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## (54) Apparatus and method for providing high performance communication between software processes.


(57) A communication interface for decoupling one software application from another software application such communications between applications are facilitated and applications may be developed in modularized fashion. The communication interface is comprised of two libraries of programs. One library manages self-describing forms which contain actual data to be exchanged as well as type information regarding data format and class definition that contain semantic information. Another library manages communications and includes a subject mapper to receive subscription requests regarding a particular subject and map them to particular communication disciplines and to particular services supplying this information. A number of communication disciplines also cooperate with the subject mapper or directly with client applications to manage communications with various other applications using the communication protocols used by those other applications.


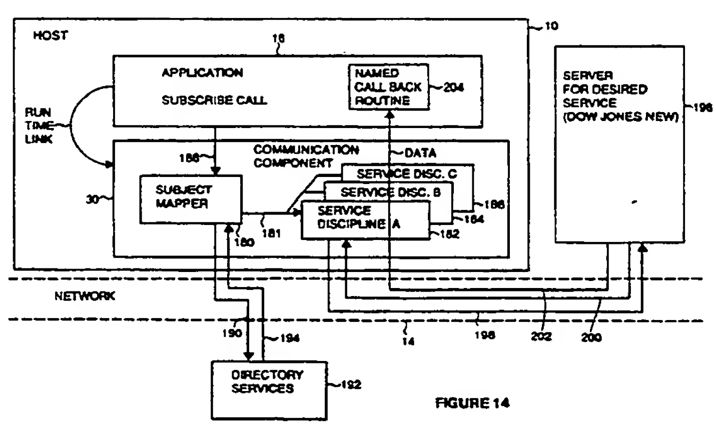


FIGURE 14

EP 0 412 232 A2

# APPARATUS AND METHOD FOR PROVIDING DECOUPLING OF DATA EXCHANGE DETAILS FOR PROVIDING HIGH PERFORMANCE COMMUNICATION BETWEEN SOFTWARE PROCESSES

## BACKGROUND OF THE INVENTION

The invention pertains to the field of decoupled information exchange between software processes running on different or even the same computer where the software processes may use different formats for data representation and organization or may use the same formats and organization but said formats and organization may later be changed without requiring any reprogramming. Also, the software processes use "semantic" or field-name information in such a way that each process can understand and use data it has received from any foreign software process, regardless of semantic or field name differences. The semantic information is decoupled from data representation and organization information.

With the proliferation of different types of computers and software programs and the ever-present need for different types of computers running different types of software programs to exchange data, there has arisen a need for a system by which such exchanges of data can occur. Typically, data that must be exchanged between software modules that are foreign to each other comprises text, data and graphics. However, there occasionally arises the need to exchange digitized voice or digitized image data or other more exotic forms of information. These different types of data are called "primitives." A software program can manipulate only the primitives that it is programmed to understand and manipulate. Other types of primitives, when introduced as data into a software program, will cause errors.

"Foreign," as the term is used herein, means that the software modules or host computers involved in the exchange "speak different languages." For example, the Motorola and Intel microprocessor widely used in personal computers and work stations use different data representations in that in one family of microprocessors the most significant byte of multibyte words is placed first while in the other family of processors the most significant byte is placed last. Further, in IBM computers text letters are coded in EBCDIC code while in almost all other computers text letters are coded in ASCII code. Also, there are several different ways of representing numbers including integer, floating point, etc. Further, foreign software modules use different ways of organizing data and use different semantic information, i.e., what each field in a data record is named and what it means.

The use of these various formats for data representation and organization means that translations either to a common language or from the language of one computer or process to the language of another computer or process must be made before meaningful communication can take place. Further, many software modules between which communication is to take place reside on different computers that are physically distant from each other and connected only local area networks, wide area networks, gateways, satellites, etc. These various networks have their own widely diverse protocols for communication. Also, at least in the world of financial services, the various sources of raw data such as Dow Jones News or Telerate™ use different data formats and communication protocols which must be understood and followed to receive data from these sources.

In complex data situations such as financial data regarding equities, bonds, money markets, etc., it is often useful to have nesting of data. That is, data regarding a particular subject is often organized as a data record having multiple "fields," each field pertaining to a different aspect of the subject. It is often useful to allow a particular field to have subfields and a particular subfield to have its own subfields and so on for as many levels as necessary. For purposes of discussion herein, this type of data organization is called "nesting." The names of the fields and what they mean relative to the subject will be called the "semantic information" for purposes of discussion herein. The actual data representation for a particular field, i.e., floating point, integer, alphanumeric, etc., and the organization of the data record in terms of how many fields it has, which are primitive fields which contain only data, and which are nested fields which contain subfields, is called the "format" or "type" information for purposes of discussion herein. A field which contains only data (and has no nested subfields) will be called a "primitive field," and a field which contains other fields will be called a "constructed field" herein.

There are two basic types of operations that can occur in exchanges of data between software modules. The first type of operation is called a "format operation" and involves conversion of the format of one data record (hereafter data records may sometimes be called "a forms") to another format. An example of such a format operation might be conversion of data records with floating point and EBCDIC fields to data records having the packed representation needed for transmission over an ETHERNET™ local area network. At the receiving process end another format operation for conversion from the ETHERNET™ packet format to integer and ASCII fields at the receiving process or software module might occur. Another

type of operation will be called herein a "semantic-dependent operation" because it requires access to the semantic. information as well as to the type or format information about a form to do some work on the form such as to supply a particular field of that form, e.g., today's IBM stock price or yesterday's IBM low price, to some software module that is requesting same.

Still further, in today's environment, there are often multiple sources of different types of data and/or multiple sources of the same type of data where the sources overlap in coverage but use different formats and different communication protocols (or even overlap with the same format and the same communication protocol). It is useful for a software module (software modules may hereafter be sometimes referred to as "applications") to be able to obtain information regarding a particular subject without knowing the network address of the service that provides information of that type and without knowing the details of the particular communication protocol needed to communicate with that information source.

A need has arisen therefore for a communication system which can provide an interface between diverse software modules, processes and computers for reliable, meaningful exchanges of data while "decoupling" these software modules and computers. "Decoupling" means that the software module programmer can access information from other computers or software processes without knowing where the other software modules and computers are in a network, the format that forms and data take on the foreign software, what communication protocols are necessary to communicate with the foreign software modules or computers, or what communication protocols are used to transit any networks between the source process and the destination process; and without knowing which of a multiple of sources of raw data can supply the requested data. Further, "decoupling," as the term is used herein, means that data can be requested at one time and supplied at another and that one process may obtain desired data from the instances of forms created with foreign format and foreign semantic data through the exercise by a communication interface of appropriate semantic operations to extract the requested data from the foreign forms with the extraction process being transparent to the requesting process.

Various. systems exist in the prior art to allow information exchange between foreign software modules with various degrees of decoupling. One such type of system is any electronic mail software which implements Electronic Document Exchange Standards including CCITT's X.409 standard. Electronic mail software decouples applications in the sense that format or type data is included within each instance of a data record or form. However, there are no provisions for recording or processing of semantic information. Semantic operations such as extraction or translation of data based upon the name or meaning of the desired field in the foreign data structure is therefore impossible. Semantic-Dependent Operations are very important if successful communication is to occur. Further, there is no provision in Electronic Mail Software by which subject-based addressing can be implemented wherein the requesting application simply asks for information by subject without knowing the address of the source of information of that type. Further, such software cannot access a service or network for which a communication protocol has not already been established.

Relational Database Software and Data Dictionaries are another example of software systems in the prior art for allowing foreign processes to share data. The shortcoming of this class of software is that such programs can handle only "flat" tables, records and fields within records but not nested records within records. Further, the above-noted shortcoming in Electronic Mail Software also exists in Relational Database Software.

## SUMMARY OF THE INVENTION

According to the teachings of the invention, there is provided a method and apparatus for providing a structure to interface foreign processes and computers while providing a degree of decoupling heretofore unknown.

The data communication interface software system according to the teachings of the invention consists essentially of several libraries of programs organized into two major components, a communication component and a data-exchange component. Interface, as the term is used herein in the context of the invention, means a collection of functions which may be invoked by the application to do useful work in communicating with a foreign process or a foreign computer or both. Invoking functions of the interface may be by subroutine calls from the application or from another component in the communications interface according to the invention.

In the preferred embodiment, the functions of the interface are carried out by the various subroutines in the libraries of subroutines which together comprise the interface. Of course, those skilled in the art will appreciate that separate programs or modules may be used instead of subroutines and may actually be

preferable in some cases.

Data format decoupling is provided such that a first process using data records or forms having a first format can communicate with a second process which has data records having a second, different format without the need for the first process to know or be able to deal with the format used by the second process. This form of decoupling is implemented via the data-exchange component of the communication interface software system.

The data-exchange component of the communication interface according to the teachings of the invention includes a forms-manager module and a forms-class manager module. The forms-manager module handles the creation, storage, recall and destruction of instances of forms and calls to the various functions of the forms-class manager. The latter handles the creation, storage, recall, interpretation, and destruction of forms-class descriptors which are data records which record the format and semantic information that pertain to particular classes of forms. The forms-class manager can also receive requests from the application or another component of the communication interface to get a particular field of an instance of a form when identified by the name or meaning of the field, retrieve the appropriate form instance, and extract and deliver the requested data in the appropriate field. The forms-class manager can also locate the class definition of an unknown class of forms by looking in a known repository of such class definitions or by requesting the class definition from the forms-class manager linked to the foreign process which created the new class of form. Semantic data, such as field names, is decoupled from data representation and organization in the sense that semantic information contains no information regarding data representation or organization. The communication interface of the invention implements data decoupling in the semantic sense and in the data format sense. In the semantic sense, decoupling is implemented by virtue of the ability to carry out semantic-dependent operations. These operations allow any process coupled to the communications interface to exchange data with any other process which has data organized either the same or in a different manner by using the same field names for data which means the same thing in the preferred embodiment. In an alternative embodiment semantic-dependent operations implement an aliasing or synonym conversion facility whereby incoming data fields having different names but which mean a certain thing are either relabeled with field names understood by the requesting process or are used as if they had been so relabeled.

Data distribution decoupling is provided such that a requesting process can request data regarding a particular subject without knowing the network address of the server or process where the data may be found. This form of decoupling is provided by a subject-based addressing system within the communication interface.

Subject-based addressing is implemented by the communication component of the communication interface of the invention. The communication component receives "subscribe" requests from an application which specifies the subject upon which data is requested. A subject-mapper module in the communication component receives the request from the application and then looks up the subject in a database, table or the like. The database stores "service records" which indicate the various server processes that supply data on various subjects. The appropriate service record identifying the particular server process that can supply data of the requested type and the communication protocol (hereafter sometimes called the service discipline) to use in communicating with the identified server process is returned to the subject-mapper module.

The subject mapper has access to a plurality of communications programs called "service disciplines." Each service discipline implements a predefined communication protocol which is specific to a server process, network, etc. The subject mapper then invokes the appropriate service discipline identified in the service record.

The service discipline is given the subject by the subject mapper and proceeds to establish communications with the appropriate server process. Thereafter, instances of forms containing data regarding the subject are sent by the server process to the requesting process via the service discipline which established the communication.

Service protocol decoupling is provided by the process described in the preceding paragraph.

Temporal decoupling is implemented in some service disciplines directed to page-oriented server processes such as Telerate™ by access to real-time data bases which store updates to pages to which subscriptions are outstanding.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram illustrating the relationships of the various software modules of the

communication interface of one embodiment of the invention to client applications and the network.

Figure 2 is an example of a form-class definition of the contructed variety.

Figure 3 is an example of another constructed form-class definition.

Figure 4 is an example of a constructed form-class definition containing fields that are themselves constructed forms. Hence, this is an example of nesting.

Figure 5 is an example of three primitive form classes.

Figure 6 is an example of a typical form instance as it is stored in memory.

Figure 7 illustrates the partitioning of semantic data, format data, and actual or value data between the form-class definition and the form instance.

Figure 8 is a flow chart of processing during a format operation.

Figure 9 is a target format-specific table for use in format operations.

Figure 10 is another target format-specific table for use in format operations.

Figure 11 is an example of a general conversion table for use in format operations.

Figure 12 is a flow chart for a typical semantic-dependent operation.

Figures 13A and 13B are, respectively, a class definition and the class descriptor form which stores this class definition.

Figure 14 is a block diagram illustrating the relationships between the subject-mapper module and the service discipline modules of the communication component to the requesting application and the service for subject-based addressing.

Figure 15 illustrates the relationship of the various modules, libraries and interfaces of an alternative embodiment of the invention to the client applications.

Figure 16 illustrates the relationships of various modules inside the communication interface of an alternative embodiment.

## DETAILED DESCRIPTION OF THE PREFERRED AND ALTERNATIVE EMBODIMENTS

Referring to Figure 1 there is shown a block diagram of a typical system in which the communications interface of the invention could be incorporated, although a wide variety of system architectures can benefit from the teachings of the invention. The communication interface of the invention may be sometimes hereafter referred to as the TIB or Teknekron Information Bus in the specification of an alternative embodiment given below. The reader is urged at this point to study the glossary of terms included in this specification to obtain a basic understanding of some of the more important terms used herein to describe the invention. The teachings of the invention are incorporated in several libraries of computer programs which, taken together, provide a communication interface having many functional capabilities which facilitate modularity in client application development and changes in network communication or service communication protocols by coupling of various client applications together in a "decoupled" fashion. Hereafter, the teachings of the invention will be referred to as the communication interface. "Decoupling," as the term is used herein, means that the programmer of client application is freed of the necessity to know the details of the communication protocols, data representation format and data record organization of all the other applications or services with which data exchanges are desired. Further, the programmer of the client application need not know the location of services or servers providing data on particular subjects in order to be able to obtain data on these subjects. The communication interface automatically takes care of all the details in data exchanges between client applications and between data-consumer applications and data-provider services.

The system shown in Figure 1 is a typical network coupling multiple host computers via a network or by shared memory. Two host computers, 10 and 12, are shown in Figure 1 running two client applications 16 and 18, although in other embodiments these two client applications may be running on the same computer. These host computers are coupled by a network 14 which may be any of the known networks such as the ETHERNET™ communication protocol, the tokenring protocol, etc. A network for exchanging data is not required to practice the invention, as any method of exchanging data known in the prior art will suffice for purposes of practicing the invention. Accordingly, shared memory files or shared distributed storage to which the host computers 10 and 12 have equal access will also suffice as the environment in which the teachings of the invention are applicable.

Each of the host computers 10 and 12 has random access memory and bulk m mory such as disk or tape drives associated therewith (not shown). Stored in these memories are the various operating system programs, client application programs, and other programs such as the programs in the libraries that together comprise the communication interface which cause the host computers to perform useful work. The libraries of programs in the communication interface provide basic tools which may be called upon by

client applications to do such things as find the location of services that provide data on a particular subject and establish communications with that service using the appropriate communication protocol.

Each of the host computers may also be coupled to user interface devices such as terminals, printers, etc. (not shown).

In the exemplary system shown in Figure 1, host computer 10 has stored in its memory a client application program 16. Assume that this client application program 16 requires exchanges of data with another client application program or service 18 controlling host computer 12 in order to do useful work. Assume also that the host computers 10 and 12 use different formats for representation of data and that application programs 16 and 18 also use different formats for data representation and organization for the data records created thereby. These data records will usually be referred to herein as forms. Assume also that the data path 14 between the host computers 10 and 12 is comprised of a local area network of the ETHERNET™ variety.

Each of the host processors 10 and 12 is also programmed with a library of programs, which together comprise the communication interfaces 20 and 22, respectively. The communication interface programs are either linked to the compiled code of the client applications by a linker to generate run time code, or the source code of the communication programs is included with the source code of the client application programs prior to compiling. In any event, the communication library programs are somehow bound to the client application. Thus, if host computer 10 was running two client applications, each client application would be bound to a communication interface module such as module 20.

The purpose of the communications interface module 20 is to decouple application 16 from the details of the data format and organization of data in forms used by application 18, the network address of application 18, and the details of the communication protocol used by application 18, as well as the details of the data format and organization and communication protocol necessary to send data across network 14. Communication interface module 22 serves the same function for application 18, thereby freeing it from the need to know many details about the application 16 and the network 14. The communication interface modules facilitate modularity in that changes can be made in client applications, data formats or organizations, host computers, or the networks used to couple all of the above together without the need for these changes to ripple throughout the system to ensure continued compatibility.

In order to implement some of these functions, the communications interfaces 20 and 22 have access via the network 14 to a network file system 24 which includes a subject table 26 and a service table 28. These tables will be discussed in more detail below with reference to the discussion of subject-based addressing. These tables list the network addresses of services that provide information on various subjects.

A typical system model in which the communication interface is used consists of users, users groups, networks, services, service instances (or servers) and subjects. Users, representing human end users, are identified by a user-ID. The user ID used in the communications interface is normally the same as the user ID or log-on ID used by the underlying operating system (not shown). However, this need not be the case. Each user is a member of exactly one group.

Groups are comprised of users with similar service access patterns and access rights. Access rights to a service or system object are grantable at the level of users and at the level of groups. The system administrator is responsible for assigning users to groups.

A "network," as the term is used herein, means the underlying "transport layer" (as the term is used in the ISO network layer model) and all layers beneath the transport layer in the ISO network model. An application can send or receive data across any of the networks to which its host computer is attached.

The communication interface according to the teachings of the invention, of which blocks 20 and 22 in Figure 1 are exemplary, includes for each client application to which it is bound a communications component 30 and a data-exchange component 32. The communications component 30 is a common set of communication facilities which implement, for example, subject-based addressing and/or service discipline decoupling. The communications component is linked to each client application. In addition, each communications component is linked to the standard transport layer protocols, e.g., TCP/IP, of the network to which it is coupled. Each communication component is linked to and can support multiple transport layer protocols. The transport layer of a network does the following things: it maps transport layer addresses to network addresses, multiplexes transport layer connections onto network connections to provide greater throughput, does error detection and monitoring of service quality, error recovery, segmentation and blocking, flow control of individual connections of transport layer to network and session layers, and expedited data transfer. The communications component provides reliable communications protocols for client applications as well as providing location transparency and network independence to the client applications.

The data-exchange component of the communications interface, of which component 32 is typical,

implements a powerful way of representing and transmitting data by encapsulating the data within self-describing data objects called forms. These forms are self-describing in that they include not only the data of interest, but also type or format information which describes the representations used for the data and the organization of the form. Because the forms include this type or format information, format operations to convert a particular form having one format to another format can be done using strictly the data in the form itself without the need for access to other data called class descriptors or class definitions which give semantic information. The meaning of semantic information in class descriptors basically means the names of the fields of the form.

The ability to perform format operations solely with the data in the form itself is very important in that it prevents the delays encountered when access must be made to other data objects located elsewhere, such as class descriptors. Since format operations alone typically account for 25 to 50% of the processing time for client applications, the use of self-describing objects streamlines processing by rendering it faster.

The self-describing forms managed by the data-exchange component also allow the implementation of generic tools for data manipulation and display. Such tools include communication tools for sending forms between processes in a machine-independent format. Further, since self-describing forms can be extended, i.e., their organization changed or expanded, without adversely impacting the client applications using said, forms, such forms greatly facilitate modular application development.

Since the lowest layer of the communications interface is linked with the transport layer of the ISO model and since the communications component 30 includes multiple service disciplines and multiple transport-layer protocols to support multiple networks, it is possible to write application-oriented protocols which transparently switch over from one network to another in the event of a network failure.

A "service" represents a meaningful set of functions which are exported by an application for use by its client applications. Examples of services are historical news retrieval services such as Dow Jones New, Quotron data feed, and a trade ticket router. Applications typically export only one service, although the export of many different services is also possible.

A "service instance" is an application or process capable of providing the given service. For a given service, several "instances" may be concurrently providing the service so as to improve the throughput of the service or provide fault tolerance.

Although networks, services and servers are traditional components known in the prior art, prior art distributed systems do not recognize the notion of a subject space or data independence by self-describing, nested data objects. Subject space supports one form of decoupling called subject-based addressing. Self-describing data objects which may be nested at multiple levels are new. Decoupling of client applications from the various communications protocols and data formats prevalent in other parts of the network is also very useful.

The subject space used to implement subject-based addressing consists of a hierarchical set of subject categories. In the preferred embodiment, a four-level subject space hierarchy is used. An example of a typical subject is: "equity.ibm.composite.trade." The client applications coupled to the communications interface have the freedom and responsibility to establish conventions regarding use and interpretations of various subject categories.

Each subject is typically associated with one or more services providing data about that subject in data records stored in the system files. Since each service will have associated with it in the communication components of the communication interface a service discipline, i.e., the communication protocol or procedure necessary to communicate with that service, the client applications may request data regarding a particular subject without knowing where the service instances that supply data on that subject are located on the network by making subscription requests giving only the subject without the network address of the service providing information on that subject. These subscription requests are translated by the communications interface into an actual communication connection with one or more service instances which provide information on that subject.

A set of subject categories is referred to as a subject domain. Multiple subject domains are allowed. Each domain can define domain-specific subject and coding functions for efficiently representing subjects in message headers.

## DATA INDEPENDENCE: The Data-Exchange Component

The overall purpose of the data-exchange component such as component 32 in Figure 1 of the com munication interface is to decouple the client applications such as application 16 from the details of data representation, data structuring and data semantics.

Referring to Figure 2, there is shown an example of a class definition for a constructed class which defines both format and semantic information which is common to all instances of forms of this class. In the particular example chosen, the form class is named Player__Name and has a class ID of 1000. The instances of forms of this class 1000 include data regarding the names, ages and NTRP ratings for tennis players. Every class definition has associated with it a class number called the class ID which uniquely identifies the class.

The class definition gives a list of fields by name and the data representation of the contents of the field. Each field contains a form and each form may be either primitive or constructed. Primitive class forms store actual data, while constructed class forms have fields which contain other forms which may be either primitive or constructed. In the class definition of Figure 2, there are four fields named Rating, Age, Last__Name and First__Name. Each field contains a primitive class form so each field in instances of forms of this class will contain actual data. For example, the field Rating will always contain a primitive form of class 11. Class 11 is a primitive class named Floating__Point which specifies a floating-point data representation for the contents of this field. The primitive class definition for the class Floating__Point, class 11, is found in Figure 5. The class definition of the primitive class 11 contains the class name, Floating__Point, which uniquely identifies the class (the class number, class 11 in this example, also uniquely identifies the class) and a specification of the data representation of the single data value. The specification of the single data value uses well-known predefined system data types which are understood by both the host computer and the application dealing with this class of forms.

Typical specifications for data representation of actual data values include integer, floating point, ASCII character strings or EBCDIC character strings, etc. In the case of primitive class 11, the specification of the data value is Floating__Point__1/1 which is an arbitrary notation indicating that the data stored in instances of forms of this primitive class will be floating-point data having two digits total, one of which is to the right of the decimal point.

Returning to the consideration of the Player__Name class definition of Figure 2, the second field is named Age. This field contains forms of the primitive class named Integer associated with class number 12 and defined in Figure 5. The Integer class of form, class 12, has, per the class definition of Figure 5, a data representation specification of Integer__3, meaning the field contains integer data having three digits. The last two fields of the class 1000 definition in Figure 2 are Last__Name and First__Name. Both of these fields contain primitive forms of a class named String__Twenty__ASCII, class 10. The class 10 class definition is given in Figure 5 and specifies that instances of forms of this class contain ASCII character strings which are 20 characters long.

Figure 3 gives another constructed class definition named Player__Address, class 1001. Instances of forms of this class each contain three fields named Street, City and State. Each of these three fields contains primitive forms of the class named String__20__ASCII, class 10. Again, the class definition for class 10 is given in Figure 5 and specifies a data representation of 20-character ASCII strings.

An example of the nesting of constructed class forms is given in Figure 4. Figure 4 is a class defini tion for instances of forms in the class named Tournament__Entry, class 1002. Each instance of a form in this class contains three fields named Tournament__Name, Player, and Address. The field Tournament__Name includes forms of the primitive class named String__Twenty__ASCII, class 10 defined in Figure 5. The field named Player contains instances of constructed forms of the class named Player__Name, class 1000 having the format and semantic characteristics given in Figure 2. The field named Address contains instances of the constructed form of constructed forms of the constructed class named Player__Address, class 1001, which has the format and semantic characteristics given in the class definition of Figure 3.

The class definition of Figure 4 shows how nesting of forms can occur in that each field of a form is a form itself and every form may be either primitive and have only one field or constructed and have several fields. In other words, instances of a form may have as many fields as necessary, and each field may have as many subfields as necessary. Further, each subfield may have as many sub-subfields as necessary. This nesting goes on for any arbitrary number of levels. This data structure allows data of arbitrary complexity to be easily represented and manipulated.

Referring to Figure 6 there is shown an instance of a form of the class of forms named Tournament__Entry, class 1002, as stored as an object in memory. The block of data 38 contains the constructed class number 1002 indicating that this is an instance of a form of the constructed class named Tournament__Entry. The block of data 40 indicates that this class of form has three fields. Those three fields have blocks of data shown at 42, 44, and 46 containing the class numbers of the forms in these fields. The block of data at 42 indicates that the first field contains a form of class 10 as shown in Figure 5. A class 10 form is a primitive form containing a 20-character string of ASCII characters as defined in the class definition for class 10 in Figure 5. The actual string of ASCII characters for this particular instance of this

form is shown at 48, indicating that this is a tournament entry for the U.S. Open tennis tournament. The block of data at 44 indicates that the second field contains a form which is an instance of a constructed form of class 1000. Reference to this class definition shows that this class is named Player__Name. The block of data 50 shows that this class of constructed form contains four subfields. Those fields contain forms of the classes recorded in the blocks of data shown at 52, 54, 56 and 58. These fields would be subfields of the field 44. The first subfield has a block of data at 52, indicating that this subfield contains a form of primitive class 11. This class of form is defined in Figure 5 as containing a flo~ting-point two-digit number with one decimal place. The actual data for this instance of the form is shown at 60, indicating that this player has an NTRP rating of 3.5. The second subfield has a block of data at 54, indicating that this subfield contains a form of primitive class 12. The class definition for this class indicates that the class is named integer and contains integer data. The class definition for class 1000 shown in Figure 2 indicates that this integer data, shown at block 62, is the player's age. Note that the class definition semantic data regarding field names is not stored in the form instance. Only the format or type information is stored in the form instance in the form of the class ID for each field.

The third subfield has a block of data at 56, indicating that this subfield contains a form of primitive class 10 named String__20__ASCII. This subfield corresponds to the field Last__Name in the form of class Player__Name, class 1000, shown in Figure 2. The primitive class 10 class definition specifies that instances of this primitive class contain a 20-character ASCII string. This string happens to define the player's last name. In the instance shown in Figure 6, the player's last name is Blackett, as shown at 64.

The last subfield has a block of data at 58, indicating that the field contains a primitive form of primitive class 10 which is a 20-character ASCII string. This subfield is defined in the class definition of class 1000 as containing the player's first name. This ASCII string is shown at 66.

The third field in the instance of the form of class 1002 has a block of data at 46, indicating that this field contains a constructed form of the constructed class 1001. The class definition for this class is given in Figure 3 and indicates the class is named Player__Address. The block of data at 68 indicates that this field has three subfields containing forms of the class numbers indicated at 70, 72 and 74. These subfields each contain forms of the primitive class 10 defined in Figure 5. Each of these subfields therefore contains a 20-character ASCII string. The contents of these three fields are defined in the class definition for class 1001 and are, respectively, the street, city and state entries for the address of the player named in the field 44. These 3-character strings are shown at 76, 78 and 80, respectively.

Referring to Figure 7, there is shown a partition of the semantic information, format information and actual data between the class definition and instances of forms of this class. The field name and format or type information are stored in the class definition, as indicated by box 82. The format or type information (in the form of the class ID) and actual data or field values are stored in the instance of the form as shown by box 72. For example, in the instance of the form of class Tournament__Entry, class 1002 shown in Figure 6, the format data for the first field is the data stored in block 42, while the actual data for the first field is the data shown at block 48. Essentially, the class number or class ID is equated by the communications interface with the specification for the type of data in instances of forms of that primitive class. Thus, the communications interface can perform format operations on instances of a particular form using only the format data stored in the instance of the form itself without the need for access to the class definition. This speeds up format operations by eliminating the need for the performance of the steps required to access a class definition which may include network access and/or disk access, which would substantially slow down the operation. Since format-type operations comprise the bulk of all operations in exchanging data between foreign processes, the data structure and the library of programs to handle the data structure defined herein greatly increase the efficiency of data exchange between foreign processes and foreign computers.

For example, suppose that the instance of the form shown in Figure 6 has been generated by a process running on a computer by Digital Equipment Corporation (DEC) and therefore text is expressed in ASCII characters. Suppose also that this form is to be sent to a process running on an IBM computer, where character strings are expressed in EBCDIC code. Suppose also that these two computers were coupled by a local area network using the ETHERNET™ communications protocol.

To make this transfer, several format operations would have to be performed. These format operations can best be understood by reference to Figure 1 with the assumption that the DEC computer is host 1 shown at 10 and the IBM computer is host 2 shown at 12.

The first format operation to transfer the instance of the form shown in Figure 6 from application 16 to application 18 would be a conversion from the format shown in Figure 6 to a packed format suitable for transfer via network 14. Networks typically operate on messages comprised of blocks of data comprising a plurality of bytes packed together end to end preceded by multiple bytes of header information which include such things as the message length, the destination address, the source address, and so on, and

having error correction code bits appended to the end of the message. Sometimes delimiters are used to mark the start and end of the actual data block.

The second format operation which would have to be performed in this hypothetical transfer would be a conversion from the packed format necessary for transfer over network 14 to the format used by the application 18 and the host computer 12.

Format operations are performed by the forms-manager modules of the communications interface. For example, the first format operation in the hypothetical transfer would be performed by the forms-manager module 86 in Figure 1, while the second format operation in the hypothetical transfer would be performed by the forms-manager module in the data-exchange component 88.

Referring to Figure 8, there is shown a flowchart of the operations performed by the forms-manager modules in performing format operations. Further details regarding the various functional capabilities of the routines in the forms-manager modules of the communications interface will be found in the functional specifications for the various library routines of the communications interface included herein. The process of Figure 8 is implemented by the software programs in the forms-manager modules of the data-exchange components in the communications interface according to the teachings of the invention. The first step is to receive a format conversion call from either the application or from another module in the communications interface. This process is symbolized by block 90 and the pathways 92 and 94 in Figure 1. The same type call can be made by the application 18 or the communications component 96 for the host computer 12 in Figure 1 to the forms-manager module in the data-exchange component 88, since this is a standard functional capability or "tool" provided by the communication interface of the invention to all client applications. Every client application will be linked to a communication interface like interface 20 in Figure 1.

Typically, format conversion calls from the communication components such as modules 30 and 96 in Figure 1 to the forms-manager module will be from a service discipline module which is charged with the task of sending a form in format 1 to a foreign application which uses format 2. Another likely scenario for a format conversion call from another module in the communication interface is when a service discipline has received a form from another application or service which is in a foreign format and which needs to be converted to the format of the client application.

The format conversion call will have parameters associated with it which are given to the forms manager. These parameters specify both the "from" format and the "to" or "target" format.

Block 98 represents the process of accessing an appropriate target format-specific table for the specified conversion, i.e., the specified "from" format and the specified "to" format will have a dedicated table that gives details regarding the appropriate target format class for each primitive "from" format class to accomplish the conversion. There are two tables which are accessed sequentially during every format conversion operation in the preferred embodiment. In alternative embodiments, these two tables may be combined. Examples of the two tables used in the preferred embodiment are shown in Figures 9, 10 and 11. Figure 9 shows a specific format conversion table for converting from DEC machines to X.409 format. Figure 10 shows a format-specific conversion table for converting from X.409 format to IBM machine format. Figure 11 shows a general conversion procedures table identifying the name of the conversion program in the communications interface library which performs the particular conversion for each "from"-"to" format pair.

The tables of Figures 9 and 10 probably would not be the only tables necessary for sending a form from the application 16 to the application 18 in Figure 1. There may be further format-specific tables necessary for conversion from application 16 format to DEC machine format and for conversion from IBM machine format to application 18 format. However, the general concept of the format conversion process implemented by the forms-manager modules of the communications interface can be explained with reference to Figures 9, 10 and 11.

Assume that the first conversion necessary in the process of sending a form from application 16 to application 18 is a conversion from DEC machine format to a packed format suitable for transmission over an ETHERNET™ network. In this case, the format conversion call received in step 90 would invoke processing by a software routine in the forms-manager module which would perform the process symbolized by block 98.

In this hypothetical example, the appropriate format-specific table to access by this routine would be determined by the "from" format and "to" format parameters in the original format conversion call received by block 90. This would cause access to the table shown in Figure 9. The format conversion call would also identify the address of the form to be converted.

The next step is symbolized by block 100. This step involves accessing the form identified in the original format conversion call and searching through the form to find the first field containing a primitive

class of form. In other words, the record is searched until a field is found storing actual data as opposed to another constructed form having subfields.

In the case of the form shown in Figure 6, the first field storing a primitive class of form is field 42. The "from" column of the table of Figure 9 would be searched using the class number 10 until the appropriate entry was found. In this case, the entry for a "from" class of 10 indicates that the format specified in the class definition for primitive class 25 is the "to" format: This process of looking up the "to" format using the "from" format is symbolized by block 102 in Figure 8. The table shown in Fiqure 9 may be "hardwired" into the code of the routine which performs the step symbolized by block 102.

Alternatively, the table of Figure 9 may be a database or other file stored somewhere in the network file system 24 in Figure 1. In such a case, the routine performing the step 102 in Figure 8 would know the network address and file name for the file to access for access to the table of Figure 9.

Next, the process symbolized by block 104 in Figure 8 is performed by accessing the general conversion procedures table shown in Figure 11. This is a table which identifies the conversion program in the forms manager which performs the actual work of converting one primitive class of form to another primitive class of form. This table is organized with a single entry for every "from"-"to" format pair. Each entry in the table for a "from"-"to" pair includes the name of the conversion routine which does the actual work of the conversion. The process symbolized by block 104 comprises the steps of taking the "from"-"to" pair determined from access to the format-specific conversion table in step 102 and searching the entries of the general conversion procedures table until an entry having a "from"-"to" match is found. In this case, the third entry from the top in the table of Figure 11 matches the "from"-"to" format pair found in the access to Figure 9. This entry is read, and it is determined that the name of the routine to perform this conversion is ASCII_ETHER. (In many embodiments, the memory address of the routine, opposed to the name, would be stored in the table.)

Block 106 in Figure 8 symbolizes the process of calling the conversion program identified by step 104 and performing this conversion routine to change the contents of the field selected in step 100 to the "to" or target format identified in step 102. In the hypothetical example, the routine ASCII_ETHER would be called and performed by step 106. The call to this routine would deliver the actual data stored in the field selected in the process of step 100, i.e., field 42 of the instance of a form shown in Figure 6, such that the text string "U.S. Open" would be converted to a packed ETHERNET™ format.

Next, the test of block 108 is performed to determine if all fields containing primitive classes of forms have been processed. If they have, then format conversion of the form is completed, and the format conversion routine is exited as symbolized by block 110.

If fields containing primitive classes of forms remain to be processed, then the process symbolized by block 112 is performed. This process finds the next field containing a primitive class of form.

Thereafter, the processing steps symbolized by blocks 102, 104, 106, and 108 are performed until all fields containing primitive classes of forms have been converted to the appropriate "to" format.

As noted above, the process of searching for fields containing primitive classes of forms proceeds serially through the form to be converted. If the next field encountered contains a form of a constructed class, that class of form must itself be searched until the first field therein with a primitive class of form is located. This process continues through all levels of nesting for all fields until all fields have been processed and all data stored in the form has been converted to the appropriate format. As an example of how this works, in the form of Figure 6, after processing the first field 42, the process symbolized by block 112 in Figure 8 would next encounter the field 44 (fields will be referred to by the block of data that contain the class ID for the form stored in that field although the contents of the field are both the class ID and the actual data or the fields and subfields of the form stored in that field). Note that in the particular class of form represented by Figure 6, the second field 44 contains a constructed form comprised of several subfields. Processing would then access the constructed form of class 1000 which is stored by the second field and proceeds serially through this constructed form until it it locates the first field thereof which contains a form of a primitive class. In the hypothetical example of Figure 6, the first field would be the subfield indicated by the class number 11 at 52. The process symbolized by block 102 would then look up class 11 in the "from" column in the table of Figure 9 and determine that the target format is specified by the class definition of primitive class 15. This "from"-"to" pair 11-15 would then be compared to the entries of the table of Figure 11 to find a matching entry. Thereafter, the process of block 106 in Figure 8 would perform the conversion program called Float1_ETHER to convert the block of data at 60 in Figure 6 to the appropriate ETHERNET™ packed format. The process then would continue through all levels of nesting.

Referring to Figure 12, there is shown a flowchart for a typical semantic-dependent operation. Semantic-dependent operations allow decoupling of applications by allowing one application to get the data in a particular field of an instance of a form generated by a foreign application provided that the field name

is known and the address of the form instance is known. The communications interface according to the teachings of the invention receives semantic-dependent operation requests from client applications in the form of Get_Field calls in the preferred embodiment where all processes use the same field names for data fields which mean the same thing (regardless of the organization of the form or the data representation of the field in the form generated by the foreign process). In alternative embodiments, an aliasing or synonym table or data base is used. In such embodiments, the Get Field call is used to access the synonym table in the class manager and looks for all synonyms of the requested field name. All field names which are synonyms of the requested field name are returned. The class manager then searches the class definition for a match with either the requested field name or any of the synonyms and retrieves the field having the matching field name.

Returning to consideration of the preferred embodiment, such Get_Field calls may be made by client applications directly to the forms-class manager modules such as the module 122 in Figure 1, or they may be made to the communications components or forms-manager modules and transferred by these modules to the forms-class manager. The forms-class manager creates, destroys, manipulates, stores and reads form-class definitions.

A Get_Field call delivers to the forms-class manager the address of the form involved and the name of the field in the form of interest. The process of receiving such a request is symbolized by block 120 in Figure 12. Block 120 also symbolizes the process by which the class manager is given the class definition either programmatically, i.e., by the requesting application, or is told the location of a data base where the class definitions including the class definition for the form of interest may be found. There may be several databases or files in the network file system 24 of Figure 1 wherein class definitions are stored. It is only necessary to give the forms-class manager the location of the particular file in which the class definition for the form of interest is stored.

Next, as symbolized by block 122, the class-manager module accesses the class definition for the form class identified in the original call.

The class manager then searches the class definition field names to find a match for the field name given in the original call. This process is symbolized by block 124.

After locating the field of interest in the class definition, the class manager returns a relative address pointer to the field of interest in instances of forms of this class. This process is symbolized by block 126 in Figure 12. The relative address pointer returned by the class manager is best understood by reference to Figures 2, 4 and 6. Suppose that the application which made the Get_Field call was interested in determining the age of a particular player. The Get_Field request would identify the address for the instance of the form of class 1002 for player Blackett as illustrated in Figure 6. Also included in the Get_Field request would be the name of the field of interest, i.e., "age". The class manager would then access the instance of the form of interest and read the class number identifying the particular class descriptor or class definition which applied to this class of forms. The class manager would then access the class descriptor for class 1002 and find a class definition as shown in Figure 4. The class manager would then access the class definitions for each of the fields of class definition 1002 and would compare the field name in the original Get_Field request to the field names in the various class definitions which make up the class definition for class 1002. In other words, the class manager would compare the names of the fields in the class definitions for classes 10, 1000, and 1001 to the field name of. interest, "Age". A match would be found in the class definition for class 1000 as seen from Figure 2. For the particular record format shown in Figure 6, the "Age" field would be the block of data 62, which is the tenth block of data in from the start of the record. The class manager would then return a relative address pointer of 10 in block 126 of Figure 12. This relative address pointer is returned to the client application which made the original Get_Field call. The client application then issues a Get_Data call to the forms-manager module and delivers to the forms-manager module the relative address of the desired field in the particular instance of the form of interest. The forms-manager module must also know the address of the instance of the form of interest which it will already have if the original Get_Field call came through the forms-manager module and was transferred to the forms-class manager. If the forms-manager module does not have the address of the particular instance of the form of interest, then the forms manager will request it from the client application. After receiving the Get_Data call and obtaining the relative address and the address of the instance of the form of interest, the forms manager will access this instance of the form and access the requested data and return it to the client application. This process of receiving the Get_Data call and returning the appropriate data is symbolized by block 128 in Figure 12.

## DATA DISTRIBUTION AND SERVICE PROTOCOL DECOUPLING BY SUBJECT-BASED ADDRESSING

AND THE USE OF SERVICE DISCIPLINE PROTOCOL LAYERS

Referring to Figure 14, there is shown a block diagram of the various software modules, files, networks, and computers which cooperate to implement two important forms of decoupling. These forms of decoupling are data distribution decoupling and service protocol decoupling. Data distribution decoupling means freeing client applications from the necessity to know the network addresses for servers providing desired services. Thus, if a particular application needs to know information supplied by, for example, the Dow Jones news service, the client application does not need to know which servers and which locations are providing data from the Dow Jones news service raw data feed.

Service protocol decoupling means that the client applications need not know the particular communications protocols necessary to traverse all layers of the network protocol and the communication protocols used by the servers, services or other applications with which exchanges of data are desired.

Data distribution decoupling is implemented by the communications module 30 in Figure 14. The communications component is comprised of a library of software routines which implement a subject mapper 180 and a plurality of service disciplines to implement subject-based addressing. Service disciplines 182, 184 and 186 are exemplary of the service disciplines involved in subject-based addressing.

Subject-based addressing allows services to be modified or replaced by alternate services providing equivalent information without impacting the information consumers. This decoupling of the information consumers from information providers permits a higher degree of modularization and flexibility than that provided by traditional service-oriented models.

Subject-based addressing starts with a subscribe call 188 to the subject mapper 180 by a client application 16 running on host computer 10. The subscribe call is a request for information regarding a particular subject. Suppose hypothetically that the particular subject was equity.IBM.news. This subscribe call would pass two parameters to the subject mapper 180. One of these parameters would be the subject equity.IBM.news. The other parameter would be the name of a callback routine in the client application 16 to which data regarding the subject is to be passed. The subscribe call to the subject mapper 180 is a standard procedure call.

The purpose of the subject mapper is to determine the network address for services which provide information on various subjects and to invoke the appropriate service discipline routines to establish communications with those services. To find the location of the services which provide information regarding the subject in the subscribe call, the subject mapper 80 sends a request symbolized by line 190 to a directory-services component 192. The directory-services component is a separate process running on a computer coupled to the network 14 and in fact may be running on a separate computer or on the host computer 10 itself. The directory-services routine maintains a data base or table of records called service records which indicate which services supply information on which subjects, where those services are located, and the service disciplines used by those services for communication. The directory-services component 192 receives the request passed from the subject mapper 180 and uses the subject parameter of that request to search through its tables for a match. That is, the directory-services component 192 searches through its service records until a service record is found indicating a particular service or services which provide information on the desired subject. This service record is then passed back to the subject mapper as symbolized by line 194. The directory-services component may find several matches if multiple services supply information regarding the desired subject.

The service record or records passed back to the subject mapper symbolized by line 194 contain many fields. Two required fields in the service records are the name of the service which provides information on the desired subject and the name of the service discipline used by that service. Other optional fields which may be provided are the name of the server upon which said service is run-ning and a location on the network of that server.

Generally, the directory-services component will deliver all the service records for which there is a subject map, because there may not be a complete overlap in the information provided on the subject by all services. Further, each service will run on a separate server which may or may not be coupled to the client application by the same network. If such multiplicity of network paths and services exists, passing all the service records with subject matter matches back to the subject mapper provides the ability for the communications interface to switch networks or switch servers or services in the case of failure of one or more of these items.

As noted above, the subject mapper 180 functions to set up communications with all of the services providing information on the desired subject. If multiple service records are passed back from the directory-services module 192, then the subject mapper 180 will set up communications with all of these services.

Upon receipt of the service records, the subject mapper will call each identified service discipline and

pass to it the subject and the service record applicable to that service discipline. Although only three service disciplines 182, 184 and 186 are shown in Figure 14, there may be many more than three in an actual system.

In the event that the directory-services component 192 does not exist or does not find a match, no service records will be returned to the subject mapper 180. In such a case, the subject mapper will call a default service discipline and pass it and the subject and a null record.

Each service discipline is a software module which contains customized code optimized for communication with the particular service associated with that service discipline.

Each service discipline called by the subject mapper 180 examines the service records passed to it and determines the location of the service with which communications are to be established. In the particular hypothetical example being considered, assume that only one service record is returned by the directory-services module 192 and that that service record identifies the Dow Jones news service running on server 196 and further identifies service discipline A at 182 as the appropriate service discipline for communications with the Dow Jones news service on server 196. Service discipline A will then pass a request message to server 196 as symbolized by line 198. This request message passes the subject to the service and may pass all or part of the service record.

The server 196 processes the request message and determines if it can, in fact, supply information regarding the desired subject. It then sends back a reply message symbolized by line 200.

Once communications are so established, the service sends all items of information pertaining to the requested subject on a continual basis to the appropriate service discipline as symbolized by path 202. In the example chosen here, the service running on server 196 filters out only those news items which pertain to IBM for sending to service discipline at 182.

Each service discipline can have a different behavior. For example, service discipline B at 184 may have the following behavior. The service running on server 196 may broadcast all news items of the Dow Jones news service on the network 14. All instances of service discipline B may monitor the network and filter out only those messages which pertain to the desired subject. Many different communication protocols are possible.

The service discipline A at 182 receives the data transmitted by the service and passes it to the named callback routine 204 in the client application 16. (The service discipline 182 was passed the name of the callback routine in the initial message from the mapper 180 symbolized by line 181.) The named callback routine then does whatever it is programmed to do with the information regarding the desired subject.

Data will continue to flow to the named callback routine 204 in this manner until the client application 16 expressly issues a cancel command to the subject mapper 180. The subject mapper 180 keeps a record of all subscriptions in existence and compares the cancel command to the various subscriptions which are active. If a match is found, the appropriate service discipline is notified of the cancel request, and this service discipline then sends a cancel message to the appropriate server. The service then cancels transmission of further data regarding that subject to the service discipline which sent the cancel request.

It is also possible for a service discipline to stand alone and not be coupled to a subject mapper. In this case the service discipline or service disciplines are linked directly to the application, and subscribe calls are made directly to the service discipline. The difference is that the application must know the name of the service supplying the desired data and the service discipline used to access the service. A database or directory-services table is then accessed to find the network address of the identified service, and communications are established as defined above. Although this software architecture does not provide data distribution decoupling, it does provide service protocol decoupling, thereby freeing the application from the necessity to know the details of the communications interface with the service with which data is to be exchanged.

More details on subject-based addressing subscription services provided by the communications interface according to the teachings of the invention are given in Section 4 of the communications interface specification given below. The preferred embodiment of the communications interface of the invention is constructed in accordance with that specification.

In actual subscribe function in the preferred embodiment is done by performing the TIB_Consume_Create library routine described in Section 4 of the specification. The call to TIB_Consume_Create includes a property list of parameters which are passed to it, one of which is the identity of the callback routine specified as My_Message_Handler in Section 4 of the specification.

In the specification, the subject-based addressing subscription service function is identified as TIBINFO. The TIBINFO interface consists of two libraries. The first library is called TIBINFO_CONSUME for data consumers. The second library is called TIBINFO_PUBLISH for data providers. An application includes one library or the other or both depending on whether it is a consumer or a provider or both. An application can

simultaneously be a consumer and a provider.

Referring to Figure 15, there is shown a block diagram of the relationship of the communications interface according to the teachings of the invention to the applications and the network that couples these applications. Blocks having identical reference numerals to blocks in Figure 1 provide similar functional capabilities as those blocks in Figure 1. The block diagram in Figure 15 shows the process architecture of the preferred embodiment. The software architecture corresponding to the process architecture given in Figure 15 is shown in block form in Figure 16.

Referring to Figure 15, the communications component 30 of Figure 1 is shown as two separate functional blocks 30A and 30B in Figure 15. That is, the functions of the communications component 30 in Figure 1 are split in the process architecture of Figure 15 between two functional blocks. A communications library 30A is linked with each client application 16, and a backend communications daemon process 30B is linked to the network 14 and to the communication library 30A. There is typically one communication daemon per host processor. This host processor is shown at 230 in Figure 15 but is not shown at all in Figure 16. Note that in Figure 15, unlike the situation in Figure 1, the client applications 16 and 18 are both running on the same host processor 230. Each client application is linked to its own copies of the various library programs in the communication libraries 30A and 96 and the form library of the data-exchange components 32 and 88. These linked libraries of programs share a common communication daemon 30B.

The communication daemons on the various host processors cooperate among themselves to insure reliable, efficient communication between machines. For subject addressed data, the daemons assist in its efficient transmission by providing low-level system support for filtering messages by subject.

The communication library 30A performs numerous functions associated with each of the application-oriented communication suites. For example, the communication library translates subjects into efficient message headers that are more compact and easier to check than ASCII subject values. The communications library also maps service requests into requests targeted for particular service instances, and monitors the status of those instances.

The data-exchange component 32 of the communications interface according to the teachings of the invention is implemented as a library called the "form library." This library is linked with the client application and provides all the core functions of the data-exchange component. The form library can be linked independently of the communication library and does not require the communication daemon 30B for its operation.

The communication daemon serves in two roles. In the subject-based addressing mode described above where the service instance has been notified of the subject and the network address to which data is to be sent pertaining to this subject, the communication daemon 30B owns the network address to which the data is sent. This data is then passed by the daemon to the communication library bound to the client application, which in turn passes the data to the appropriate callback routine in the client application. In another mode, the communication daemon filters data coming in from the network 14 by subject when the service instances providing data are in a broadcast mode and are sending out data regarding many different subjects to all daemons on the network.

The blocks 231, 233 and 235 in Figure 15 represent the interface functions which are implemented by the programs in the communication library 30A and the form library 32. The TIBINFO interface 233 provides subject-based addressing services by the communication paradigm known as the subscription call. In this paradigm, a data consumer subscribes to a service or subject and in return receives a continuous stream of data about the service or subject until the consumer explicitly terminates the subscription (or a failure occurs). A subscription paradigm is well suited to real-time applications that monitor dynamically changing values, such as a stock price. In contrast, the more traditional request/reply communication is ill suited to such real-time applications, since it requires data consumers to "poll" data providers to learn of changes.

The interface 235 defines a programmatic interface to the protocol suite and service comprising the Market Data Subscription Service (MDSS) sub-component 234 in Figure 16. This service discipline will be described more fully later. The RMDP interface 235 is a service address protocol in that it requires the client application to know the name of the service with which data is to be exchanged.

In Figure 16 there is shown the software architecture of the system. A distributed communications component 232 includes various protocol engines 237, 239 and 241. A protocol engine encapsulates a communication protocol which interfaces service discipline protocols to the particular network protocols. The distributed component 232 is coupled to a variety of service disciplines 234, 236 and 238. The service discipline 234 has the behavior which will herein be called Market Data Subscription Service. This protocol allows data consumers to receive a continuous stream of data, tolerant of individual data sources. This protocol suite provides mechanisms for administering load-balancing and entitlement policies.

The service discipline labeled MSA, 236, has yet a different behavior. The service discipline labeled

SASSII, 238, supports subject-based address subscription services as detailed above.

The software architecture detailed in Figures 15 and 16 represents an alternative embodiment to the embodiment described above with reference to Figures 1-14.

Normally, class-manager modules store the class definitions needed to do semantic-dependent operations in RAM of the host machine as class descriptors. Class definitions are the specification of the semantic and formation information that define a class. Class descriptors are memory objects which embody the class definition. Class descriptors are stored in at least two ways. In random access memory (RAM), class descriptors are stored as forms in the format native to the machine and client application that created the class definition. Class descriptors stored on disk or tape are stored as ASCII strings of text.

When the class-manager module is asked to do a semantic-dependent operation, it searches through its store of class descriptors in RAM and determines if the appropriate class descriptor is present. If it is, this class descriptor is used to perform the operation detailed above with reference to Figure 12. If the appropriate class descriptor is not present, the class manager must obtain it. This is done by searching through known files of class descriptors stored in the system files 24 in Figure 1 or by making a request to the foreign application that created the class definition to send the class definition to the requesting module. The locations of the files storing class descriptors are known to the client applications, and the class-manager modules also store these addresses. Often, the request for a semantic-dependent operation includes the address of the file where the appropriate class descriptor may be found. If the request does not contain such an address, the class manager looks through its own store of class descriptors and through the files identified in records stored by the class manager identifying the locations of system class descriptor files.

If the class manager asks for the class descriptor from the foreign application that generated it, the foreign application sends a request to its class manager to send the appropriate class descriptor over the network to the requesting class manager or the requesting module. The class descriptor is then sent as any other form and used by the requesting class manager to do the requested semantic-dependent operation.

If the class manager must access a file to obtain a class descriptor, it must also convert the packed ASCII representation in which the class descriptors are stored on disk or tape to the format of a native form for storage in RAM. This is done by parsing the ASCII text to separate out the various field names and specifications of the field contents and the class numbers.

Figures 13A and 13B illustrate, respectively, a class definition and the structure and organization of a class descriptor for the class definition of Figure 13A and stored in memory as a form. The class definition given in Figure 13A is named Person_Class and has only two fields, named last and first. Each of these fields is specified to store a 20-character ASCII string.

Figure 13B has a data block 140 which contains 1021 indicating that the form is a constructed form having a class number 1021. The data block at 142 indicates that the form has 3 fields. The first field contains a primitive class specified to contain an ASCII string which happens to store the class name, Person_Class, in data block 146. The second field is of a primitive class assigned the number 2, data block 148, which is specified to contain a boolean value, data block 150. Semantically, the second field is defined in the class definition for class 1021 to define whether the form class is primitive (true) or constructed (false). In this case, data block 150 is false indicating that class 1021 is a constructed class. The third field is a constructed class given the class number 112 as shown by data block 152. The class definition for class 1021 defines the third field as a constructed class form which gives the names and specifications of the fields in the class definition. Data block 154 indicates that two fields exist in a class 112 form. The first field of class 112 is itself a constructed class given the class number 150, data block 156, and has two subfields, data block 158. The first subfield is a primitive class 15, data block 160, which is specified in the class definition for class 150 to contain the name of the first field in class 1021. Data block 162 gives the name of the first field in class 1021. The second subfield is of primitive class 15, data block 164, and is specified in the class definition of class 150 (not shown) to contain an ASCII string which specifies the representation, data block 166, of the actual data stored in the first field of class 1021. The second field of class 112 is specified in the class definition of class 112 to contain a constructed form of class 150, data block 168, which has two fields, data block 170, which give the name of the next field in class 1021 and specify the type of representation of the actual data stored in this second field.

## SPECIFICATION

There follows a more detailed specification of the various library programs and the overall structure and functioning of an embodiment of the communication interface according to the teachings of the invention.

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CONTENTS



## 1. Introduction

The Teknekron Information Bus™ (TIB™) is a distributed software component designed to facilitate the exchange of data among applications executing in a real-time, distributed environment. It is built on top of industry standard communication protocols (TCP/IP) and data-exchange standards (e.g., X.400).

This document describes a "prerelease" version of the TIB Application Programmatic Interface (API) and contains interface descriptions of all core TIB components. It has been distributed for information purposes only. Readers should note that the interfaces described herein are subject to change. Although Teknekron does not anticipate any major changes to the interface specification contained herein, it does expect minor changes to be suggested and implemented as a result of the distribution process.

The document is organized as follows. Section 2 gives an architectural overview of the TIB. Section 3 describes the Reliable Market Data Protocol. This general purpose protocol is particularly well suited to the requirements of the page-based market data services. It is also often used for bulletin and report distribution. Section 4 describes TIBINFO, an interface supporting Subject-based Addressing. Section 5 describes a component and its interface that supports a very flexible and extensible data-exchange standard. This component is called TIBFORMS. The Appendix contains (UNIX-like) manual pages for the core interfaces.

## 2. Architectural Overview

### 2.1 Introduction

The Teknekron Information Bus (TIB) is comprised of two major components: the (application-oriented) data communication component and the data-exchange component. These are depicted in Figure 2.1. In addition, a set of presentation tools and a set of support utilities have been built around these components to assist the application developer in the writing of TIB-based applications.

The (application-oriented) data communication component implements an extensible framework for implementing high-level, communication protocol suites. Two protocol suites have been implemented that are tailored toward the needs of fault-tolerant, real-time applications that communicate via messages. Specifically, the suites implement subscription services that provide communication support for monitoring dynamically changing values over a network. Subscription services implement a communication paradigm well suited to distributing market data from, for example, Quotron or Telerate.

One of the protocol suites supports a traditional service-oriented cooperative processing model. The other protocol suite directly supports a novel information-oriented, cooperative processing model by implementing subject-based addressing. Using this addressing scheme, applications can request information by subject through a general purpose interface. Subject-based addressing allowing information consumers to be decoupled from information producers; thereby, increasing the modularity and extensibility of the system.

The application-oriented protocol suites are built on top of a common set of communication facilities called the distributed communications component, depicted as a sublayer in Figure 2.1. In addition to providing reliable communications protocols, this layer provides location transparency and network independence to its clients.

The layer is built on top of standard transport-layer protocols (e.g., TCP/IP) and is capable of supporting multiple transport protocols. The data-exchange component implements a powerful way of representing and transmitting data. All data is encapsulated within self-describing data objects, called TIB-forms or, more commonly, simply forms. Since TIB forms are self-describing, they admit the implementation of generic tools for data manipulation and display. Such tools include communication tools for sending forms between processes in a machine-independent format. Since a self-describing form can be extended without adversely impacting the applications using it, forms greatly facilitate modular application development.

The two major components of TIB were designed so that applications programmers can use them independently or together. For example, forms are not only useful for communicating applications that share data, but also for non-communicating applications that desire to use the generic tools and modular programming techniques supported by forms. Such applications, of course, do not need the communication services of the TIB. Similarly, applications using subject-based addressing, for example, need not transmit forms, but instead can transmit any data structure. Note that the implementation of the communication component does use forms, but it does not require applications to use them.

## 2.2 System Model

The system model supported by the TIB consists of users, user groups, networks, services, service instances (or servers), and subjects.

The concept of a user, representing a human "end-user," is common to most systems. A user is identified by a user-id. The TIB user-id is normally the same as the user-id (or logon id) supported by the underlying operating system, but it need not be.

Each user is a member of a exactly one group. The intention is that group should be composed of users with similar service access patterns and access rights. Access rights to a service or system object are grantable at the level of users and at the level of groups. The system administrator is responsible for assigning users to groups.

A network is a logical concept defined by the underlying transport layer and is supported by the TIB. An application can send or receive across any of the networks that its host machine is attached to. It also supports all gateways functions and internetwork routing that is supported by the underlying transport-layer protocols.

Since the lowest layer of the TIB communication component supports multiple networks, application-oriented protocols can be written that transparently switchover from one network to another in the event of a network failure.

A service represents a meaningful set of functions that are exported by an application for use by its clients. Examples of services are an historical news retrieval service, a Quotron datafeed, and a trade ticket router. An application will typically export only one service, although it can export many different services.

A service instance is an application process capable of providing the given service. (Sometimes these are called "server processes.") For a given service, several instances may be concurrently providing it, so as to improve performance or to provide fault tolerance. Application-oriented communication protocols in the TIB can implement the notion of a "fault-tolerant" service by providing automatic switchover from a failed service instance to an operational one providing the same service.

Networks, services, and servers are traditional components of a system model and are implemented in one fashion or another in most distributed systems. On the other hand, the notion of a subject is novel to the information model implemented by the TIB.

The subject space consists of a hierarchical set of subject categories. The current release of the TIB supports a 4 level hierarchy, as illustrated by the following well formed subject:
"equity.ibm.composite.trade." The TIB itself enforces no policy as to the interpretation of the various subject categories. Instead, the applications have the freedom and responsibility to establish conventions on use and interpretation of subject categories.

Each subject is typically associated with one or more services producing data about that subject. The subject-based protocol suites of the TIB are responsible for translating an application's request for data on a subject into communication connections to one or more service instances providing information on that subject.

A set of subject categories is referred to as a subject domain. The TIB provides support for multiple subject domains. This facility is useful, for example, when migrating from one domain to another domain. Each domain can define domain-specific subject encoding functions for efficiently representing subjects in message headers.

### 2.3 Process Architecture

The communication component of the TIB is a truly distributed system with its functions being split between a frontend TIB/communication library, which is linked with each application, and a backend TIB/communication daemon process, for which there is typically one per host processor. This process architecture is depicted Figure 2.2. Note that this functional split between TIB library and TIB daemon is completely transparent to the application. In fact, the application is completely unaware of the existence of the TIB daemon, with the exception of certain failure return codes.

The TIB daemons cooperate among themselves to ensure reliable, efficient communication between machines. For subject-addressed data, they assist in its efficient transmission by providing low-level system support for filtering messages by subject.

The TIB/communication library performs numerous functions associated with each of the application-oriented communication suites. For example, the library translates subjects into efficient message headers that are more compact and easier to check than ASCII subject values. It also maps service requests into requests targeted for particular service instances, and monitors the status of those instances.

The data-exchange component of TIB is implemented as a library, call the TIB/form library, that is linked with the application. This library provides all of the core functions of the data-exchange component and can be linked independently of the TIB/communication library. The TIB/form library does not require the TIB/communication daemon.

### 2.4 Communication Component

The TIB Communication Component consists of 3 subcomponents: the lower-level distributed communication component (DCC), and two high-level application-oriented communication protocol suites-the Market Data Subscription Service (MDSS), and the Subject-Addressed Subscription Service (SASS).

The high-level protocol suites are tailored around a communication paradigm known as a subscription. In this paradigm, a data consumer "subscribes" to a service or subject, and in return receives a continuous stream of data about the service or subject until the consumer explicitly terminates the subscription (or a failure occurs). A subscription paradigm is well suited for realtime applications that monitor dynamically changing values, such as a stock's price. In contrast, the more traditional request/reply communication paradigm is ill-suited for such realtime applications, since it requires data consumers to "poll" data providers to learn of changes.

The principal difference between the two high-level protocols is that the MDSS is service-oriented and SASS is subject-oriented. Hence, for example, MDSS supports the sending of operations and messages to services, in addition to supporting subscriptions; whereas, SASS supports no similar functionality.

#### 2.4.1 Market Data Subscription Service

##### 2.4.1.1 Overview

MDSS allows data consumers to receive a continuous stream of data, tolerant of failures of individual data sources. This protocol suite provides mechanisms for administering load balancing and entitlement policies.

Two properties distinguish the MDSS protocols from the typical client/server protocols (e.g. RPC). First, subscriptions are explicitly supported, whereby changes to requested values are automatically propagated to clients. Second, clients request (or subscribe) to a service, as opposed to a server, and it is the responsibility of the MDSS component to forward the client's request to an available server. The MDSS is then responsible for monitoring the server connection and reestablishing if it fails, using a different server, if necessary.

The MDSS has been designed to meet the following important objectives:

(1) Fault tolerance. By supporting automatic switchover between redundant services, by explicitly supporting dual (or triple) networks, and by utilizing the fault-tolerant transmission protocols implemented in the DCC (such as the "reliable broadcast protocols"), the MDSS ensures the integrity of a subscription against all single point failures. An inopportune failure may temporarily disrupt a subscription, but the MDSS is designed to detect failures in a timely fashion and to quickly search for an alternative

communication path and/or server. Recovery is automatic as well.

(2) Load balancing. The MDSS attempts to balance the load across all operational servers for a service. It also rebalances the load when a server fails or recovers. In addition, the MDSS supports server assignment policies that attempts to optimize the utilization of scarce resources such as "slots" in a page cache or bandwidth across an external communication line.

(3) Network efficiency. The MDSS supports the intelligent multicast protocol implemented in the DCC. This protocol attempts to optimize the limited resources of both network bandwidth and processor I/O bandwidth by providing automatic, dynamic switchover from point-to-point communication protocols to broadcast protocols. For example, the protocol may provide point-to-point distribution of Telerate page 8 to the first five subscribers and then switch all subscribers to broadcast distribution when the sixth subscriber appears.

(4) High-level communication interface. The MDSS implements a simple, easy-to-use application development interface that mask most of the complexities of programming a distributed system, including locating servers, establishing communication connections, reacting to failures and recoveries, and load balancing.

#### 2.4.1.2 Functionality

The MDSS supports the following core functions:

get

MDSS establishes a fault-tolerant connection to a server for the specified service and "gets" (i.e., retrieves) the current value of the specified page or data element. The connection is subscription based so that updates to the specified page are automatically forwarded.

halt

"halt" the subscription to the specified service.

derive

sends a modifier to the server that could potentially change the subscription.

The MDSS protocol has been high-optimized to support page-oriented market data feed, and this focus has been reflected in the choice of function names. However, the protocol suite itself is quite general and supports the distribution of any type of data. Consequently, the protocol suite is useful and is being used in other contexts (e.g., data distribution in an electronic billboard).

### 2.4.2 Subject-Addressed Subscription Service (SASS)

#### 2.4.2.1 Overview

The SASS is a sophisticated protocol suite providing application developers a very high-level communications interface that fully supports the information-oriented, cooperative processing model. This is achieved through the use of subject-based addressing.

The basic idea behind subject-based addressing and the SASS's implementation of it is straightforward. Whenever an application requires a piece of data, especially, data that represents a dynamically changing value (e.g. a stock price), the application simply subscribes to that data by specifying the appropriate subject. For example, in order to receive all trade tickets on IBM, an application may issue the following subscription: "trade_ticket.IBM". Once an application has subscribed to a particular subject, it is the responsibility of the SASS to choose one or more service instances providing information on that subject. The SASS then makes the appropriate communications connections and (optionally) notifies the service instances providing the information.

The SASS has been designed to meet several important objectives:

(1) Decoupling information consumers from information providers. Through the use of subject-based addressing, information consumers can request information in a way that is independent of the application producing the information. Hence, the producing application can be modified or supplanted by a new application providing the same information without affecting the consumers of the information.

(2) Efficiency. Support for filtering messages by subject is built into the low levels of the TIB daemon, where it can be very efficient. Also, the SASS supports filtering data at the producer side: data that is not currently of interest to any application can simply be discarded prior to placing in on the network;

thereby, conserving network bandwidth and processor I/O bandwidth.

(3) High-level communication interface. The SASS interface greatly reduces the complexities of programming a distributed application in three ways. First, the consumer requests information by subject, as opposed to by server or service. Specifying information at this level is easier and more natural than at the service level. Also, it insulates the program from changes in service providers (e.g., a switch from IDN to Ticker 3 for equity prices). Second, the SASS presents all data through a simple uniform interface-a programmer needing information supplied by three services need not learn three service-specific protocols, as he would in a traditional processing model. Third, the SASS automates many of the hard or error-prone tasks, such as searching for an appropriate service instance, and establishing the correct communication connection.

#### 2.4.2.2 Functionality

For a data consumer, the SASS provides three basic functions:

subscribe

where the consumer requests information on a real-time basis on one or more subjects. The SASS components sets up any necessary communication connections to ensure that all data matching the given subject(s) will be delivered to the consumer. The consumer can specify that data be delivered either asynchronously (interrupt-driven) or synchronously. A subscription may result in the producer service instance being informed of the subscription. This occurs whenever the producer has set up a registration procedure for its service. This notification of the producer via any specified registration procedure is transparent to the consumer.

cancel

which is the opposite of subscribe. The SASS component gracefully closes down any dedicated communication channels, and notifies the producer if an appropriate registration procedure exists for the service.

receive

receive and "callbacks" are two different ways for applications to receive messages matching their subscriptions. Callbacks are asynchronous and support the event driven programming style-a style that is particularly well-suited for applications requiring realtime data exchange. "Receive" supports a traditional synchronous interface for message receipt.

For a data producer, the SASS provides a complementary set of functions.

Note that an application can be both a producer and a consumer with respect to the SASS, and this is not uncommon.

### 2.4.3 Distributed Communication Component

#### 2.4.3.1 Overview

The Distributed Communication Component (DCC) provides communication services to higher-level TIB protocols, in particular, it provide several types of fault transport protocols.

The DCC is based on several important objectives:

(1) The provision of a simple, stable, and uniform communication model. This objective offers several benefits. First, it offers increased programmer productivity by shielding developers from the complexities of a distributed environment; locating a target process, establishing communications with it, and determining when something has gone awry are all tasks best done by a capable communications infrastructure, not by the programmer. Second, it reduces development time, not only by increasing programmer productivity, but also by simplifying the integration of new features. Finally, it enhances configurability by keeping applications unaware of the physical distribution of other components. This prevents developers from building in dependencies based on a particular physical configuration. (Such dependencies would complicate subsequent reconfigurations.)

(2) Portability through encapsulation of important system structures. This objective achieves importance when migration to a new hardware or software environment becomes necessary. The effort expended in shielding applications from the specific underlying communication protocols and access methods pays off handsomely at that time. By isolating the required changes in a small portion of the system (in this case, the DCC), applications can be ported virtually unchanged, and the firm's application investment is

protected.

(3) Efficiency. This is particular important in this component. To achieve this, the DCC builds on top of less costly "connectionless" transport protocols in standard protocol suites (e.g., TCP/IP and OSI). Also, the DCC has been carefully designed to avoid the most costly problem in protocols: the proliferation of data "copy" operations.

The DCC achieves these objectives by implementing a layer of services on top of the basic services provided by vendor-supplied software. Rather than re-inventing basic functions like reliable data transfer or flow-control mechanisms, the DCC concentrates on shielding applications from the idiosyncrasies of any one particular operating system. Examples include the hardware-oriented interfaces of the MS-DOS environment, or the per-process file descriptor limit of UNIX. By providing a single, unified communication tool that can be easily replicated in many hardware or software environment, the DCC fulfills the above objectives.

#### 2.4.3.2 Functionality

The DCC implements several different transmission protocols to support the various interaction paradigms, fault-tolerance requirements, and performance requirements imposed by the high-level protocols. Two of the more interesting protocols are reliable broadcast and intelligent multicast protocols.

Standard broadcast protocols are not reliable and are unable to detect lost messages. The DCC reliable broadcast protocols ensure that all operational hosts either receive each broadcast message or detects the loss of the message. Unlike many so-called reliable broadcast protocols, lost messages are retransmitted on a limited, periodic basis.

The intelligent multicast protocol provides a reliable datastream to multiple destinations. The novel aspect of the protocol is that it can dynamically switch from point-to point transmission to broadcast transmission in order to optimize the network and processor load. The switch from point-to-point to broadcast (and vice versa) is transparent to higher-level protocols. This protocol admits the support of a much larger number of consumers than would be possible using either point-to-point or broadcast alone. The protocol is built on top of other protocols within the DCC.

Currently, all DCC protocols exchange data only in discrete units, i.e., "messages" (in contrast to many Transport protocols). The DCC guarantees that the messages originating from a single process are received in the order sent.

The DCC contains fault-tolerant message transmission protocols that support retransmission in the event of a lost message. The package guarantees "at-most-once" semantics with regards to message delivery and makes a best attempt to ensure "exactly once" semantics.

The DCC contains no exposed interfaces for use by application developers.

## 3. RELIABLE MARKET DATA PROTOCOL

### 3.1 Introduction

The Reliable Market Data Protocol (RMDP) defines a programmatic interface to the protocol suite and services comprising the Market Data Subscription Service (MDSS) TIB subcomponent. RMDP allows market data consumers to receive a continuous stream of data, based on a subscription request to a given service. RMDP tolerates failures of individual servers, by providing facilities to automatically reconnect to alternative servers providing the same service. All the mechanisms for detecting server failure and recovery, and for hunting for available servers are implemented in the RMDP library. Consequently, application programs can be written in a simple and naive way.

The protocol provides mechanisms for administering load balancing and entitlement policies. For example, consider a trading room with three Telerate lines. To maximize utilization of the available bandwidth of those Telerate lines, the system administrator can "assign" certain commonly used pages to particular servers, i.e., page 5 to server A, page 405 to server B, etc. Each user (or user group) would be assigned a "default" server for pages which are not explicitly preassigned. (These assignments are recorded in the TIB Services Directory.)

To accommodate failures, pages or users are actually assigned to prioritized list of servers. When a server experiences a hardware or software failure, RMDP hunts for and connects to the next server on the

list. When a server recovers, it announces its presence to all RMDP clients, and RMDP reconnects the server's original clients to it. (Automatic reconnection avoids situations where some servers are overloaded while others are idle.) Except for status messages, failure and recovery reconnections are transparent to the application.

The MDSS protocol suite, including RMDP, is built on top of the DCC and utilizes the reliable communication protocols implemented in that component. In particular, the MDSS suite utilizes the reliable broadcast protocols and the intelligent multicast protocol provided therein. RMDP supports both LANs and wide area networks (WANs). RMDP also supports dual (or multiple) networks in a transparent fashion.

RMDP is a "service-addressed" protocol; a complementary protocol, TIBINFO, supports "subject-based addressing."

### 3.2 Programmatic Interface

RMDP programs are event-driven. All RMDP function calls are non-blocking: even if the call results in communication with a server, the call returns immediately. Server responses, as well as error messages, are returned at a later time through an application-supplied callback procedure.

The principal object abstraction implemented in RMDP is that of an Rstream, a "reliable stream," of data that is associated with a particular subscription to a specified service. Although, due to failures and recoveries, different servers may provide the subscription data at different times, the Rstream implements the abstraction of a single unified data stream. Except for short periods during failure or recovery reconnection, an Rstream is connected to exactly one server for the specified service. An application may open as many Rstreams as needed, subject only to available memory.

An Rstream is bidirectional--in particular, the RMDP client can send control commands and messages to the connected server over the Rstream. These commands and messages may spur responses or error messages from the server, and in one case, a command causes a "derived" subscription to be generated. Regardless of cause, all data and error messages (whether remotely or locally generated) are delivered to the client via the appropriate Rstream.

The RMDP interface is a narrow interface consisting of just six functions, which are described below.

```
void
rmdp__SetProp(property, value)
rmdp__prop__t property;
caddr__t value;
```

Used to set the values of RMDP properties. These calls must be made before the call to rmdp__Init(). Required properties are marked with ? in the list below. Other properties are optional. The properties currently used are:

'RMDP__CALLBACK

Pointer to the callback function. See the description of callback below.

RMDP__SERVICE__MAP

The name of Services Directory to be used in lieu of the standard directory.

RMDP__GROUP

The user group used to determine the appropriate server list. Should be prefixed with '+'. Default is group is "+" (i.e. the null group).

RMDP__RETRY__TIME

The number of seconds that the client will wait between successive retries to the same server, e.g., in the case of cache full." Default is 30.

RMDP_QUIET_TIME

The time in seconds that a stream may be "quiet" before the protocol assumes that the server has died and initiates a "hunt" for a different server. Default is 75.

RMDP_VERIFY_TIME

The time in seconds between successive pings of the server by the client. Default is 60.

RMDP_APP_NAME

The name of the application i.e. "telerate", "reuters" etc. If this property is set, then the relevant entries from the Service Directory will be cached.

void

rmdp_Init();

This initializes the internal data structures and must be called prior to any calls to rmdp_Get().

RStream

rmdp_Get(service, request, host)

char *service, *request, *host;

This is used to get a stream of data for a particular service and subscription 'request' . For the standard market data services, the request will be the name of a page (e.g., "5", "AANN"). If 'host' is non-NULL, then the RMDP will only use the server on the given host. In this case, no reconnection to alternative servers will be attempted upon a server failure. If 'host' is NULL, then RMDP will consult the TIB Services Directory to identify a list of server alternatives for the request. 'rstream' is an opaque value that is used to refer to the stream. All data passed to the application's callback function will be identified by this value.

An error is indicated by Rstream rstream = = NULL.

```
RStream
rmdp_Derive(rstream, op)
RStreamold;
char            *op;
```

This generates a new subscription and, hence, a new 'RStream' from an existing subscription. 'command' is a string sent to the server, where it is interpreted to determine the specific derivation.

The standard market data servers understand the following commands: "n" for next-page, "p" for previous-page and "t XXXX" for time-page.

Derived streams cannot be recovered in the case of server failure. If successful, an Rstream is returned, otherwise NULL is returned.

```
void
rmdp_Message(rstream, msg)
RStreamrstream;
char              *msg;
```

Sends the string 'msg' to the server used by 'rstream'. The messages are passed directly to the server, and are not in any way affected by the state of the stream. The messages are understood by the standard market data servers include "rr <PAGE NAME>" to rerequest a page, and "q a" to request the server's network address. Some messages induce a response from the server (such as queries). In this case, the response will be delivered to all streams that are connected to the server.

void

rmdp_Halt(rstream)

RStreamrstream;

This gracefully halts the 'rstream'.

```
void
callback(rstream, msgtype, msg, act, err)
RStreamrstream;
mdp_msg_t       msgtype;
char            *msg;
mdp_act_t       act;
mdp_err_t       err;
```

This is the callback function which was registered with rmdp_SetProp(RMDP_CALLBACK, callback). 'rstream' is the stream to which the message pertains. 'msgtype' can be any of the values defined below see "RMDP Message Type"). 'msg' is a string which may contain vt100 compatible escape sequences, as in MDSS. (It will NOT however be prefaced with an ^[[...E. That role is assumed by the parameter 'msgtype'.)

The last two parameters are only meaningful if 'msgtype' is MDP_MSG_STATUS. 'act' can be any of the values found in "RMDP Action Type" (see below), but special action is necessary only if act = = 'MDP_ACT_CANCEL'. The latter indicates that the stream is being canceled and is no longer valid. It is up to the application to take appropriate action. In either case, 'err' can be any of the values found in "RMDP Error Type" (see below), and provides a description of the status.

RMDP Message Types (mdp_msg_t)

The message types are listed below. These types are defined in the underlying (unreliable) Market Data Protocol (MDP) and are exported to the RMDP.

| | |
|---|---|
| MDP_MSG_BAD = -1 | |
| MDP_MSG_DATA = 0 | Page data message. |
| MDP_MSG_STATUS = 1 | Status/error message. |
| MDP_MSG_OOB = 2 | "Out of Band" message, e.g., time stamp. |
| MDP_MSG_QUERY = 3 | Query result. |

RMDP Action Type (mdp__act__t)

The action types are listed below. These action types inform the RMDP clients of activities occurring in the lower level protocols. Generally speaking, they are "for your information only" messages, and do not require additional actions by the RMDP client. The exception is the "MDP__ACT__CANCEL" action, for which there is no recovery. These types are defined in the underlying (unreliable) Market Data Protocol (MDP) and are exported to the RMDP.
MDP__ACT__OK = 0
No unusual action required.
MDP__ACT__CANCEL = 1
The request cannot be serviced, cancel the stream, do not attempt to reconnect. (E.g., invalid page name.)
MDP__ACT__CONN__FIRST = 2
The server is closing the stream; the first server in the alternatives list is being tried. (E.g., the server is shedding "extra" clients for load balancing.)
MDP__ACT__CONN__NEXT = 3
The server is closing the stream; the next server in the alternatives list is being tried. (E.g., the server's line to host fails.)
MDP__ACT__LATER = 4
Server cannot service request at this time; will resubmit request later, or try a different server. (E.g., Cache full.)
MDP__ACT__RETRY = 5
Request is being retried immediately.

RMDP Error Types (mdp__err__t)

Description of error, for logging or reporting to end user. These types are defined in the underlying (unreliable) Market Data Protocol (MDP) and are exported to the RMDP. MDP__ERR__OK = 0
MDP__ERR__LOW = 1
MDP__ERR__QUIET = 2
MDP__ERR__INVAL = 3
MDP__ERR__RESRC = 4
MDP__ERR__INTERNAL = 5
MDP__ERR__DELAY = 6
MDP__ERR__SYS = 7
MDP__ERR__COMM = 8

## 4. Subject-Addressed Subscription Service:TIBINFO

### 4.1 Introduction

TIBINFO defines a programmatic interface to the protocols and services comprising the TIB subcomponent providing Subject-Addressed Subscription Services (SASS). The TIBINFO interface consists of libraries: TIBINFO__CONSUME for data consumers, and TIBINFO__PUBLISH for data providers. An applica-

tion includes one library or the other or both depending on whether it is a consumer or provider or both. An application can simultaneously be a consumer and a producer.

Through its support of Subject-Based Addressing, TIBINFO supports a information-oriented model of cooperative processing by providing a method for consumers to request information in a way that is independent of the service (or services) producing the information. Consequently, services can be modified or replaced by alternate services providing equivalent information without impacting the information consumers. This decoupling of information consumers from information providers permits a higher degree of modularization and flexibility than that permitted by traditional service-oriented processing models.

For Subject-Based Addressing to be useful in a real time environment, it must be efficiently implemented. With this objective in mind, support for Subject-Based Addressing has been built into the low levels of the Distributed Communications Component. In particular, the filtering of messages by subject is performed within the TIB daemon itself.

## 4.2 Concepts

Subject

The subject space is hierarchical. Currently, a 4-level hierarchy is supported of the following format:
major[.minor[.qualifier1[.qualifier2]]]
where '[' and ']' are metacharacters that delimit an optional component. major, minor, qualifier1 and qualifier2 are called subject identifiers. A subject identifier is a string consisting of the printable ascii characters excluding '.', '?', and '*'. A subject identifier can be an empty string, in which case it will match with any subject identifier in that position. The complete subject, including the '.' separators, can not exceed 32 characters. Subjects are case sensitive.

Some example of valid subjects are listed below: The comments refer to the interpretation of subjects on the consume side. (The publish-side semantics are slightly different.)

| | |
|---|---|
| equity.ibm.composite.quote | |
| equity..composite.quote | matches any minor subject |
| equity.ibm | matches any qualifier1 and qualifier2 |
| equity.ibm. | same as above |

Within the TIBINFO and the SASS, subjects are not interpreted. Hence, applications are free to establish conventions on the subject space. It should be noted that SASS components first attempt to match the major and minor subject identifiers first. As a consequence, although applications can establish the convention that "equity.ibm" and "..equity.ibm" are equivalent subjects, subscriptions to "equity.ibm" will be more efficiently processed.

Stream

A stream is an abstraction for grouping subscriptions. The subscriptions on a stream share a common set of properties, notably the same message handler (i.e., "callback" routine) and the same error handler. All subscriptions on a stream can be "canceled" simply by destroying the stream.

A stream imposes little overhead on the system. They can therefore be freely created and destroyed.

Protocol Engines, Service Disciplines, and Subject Mappers

The SASS and DCC components implement many support services in order to provide the functionality in TIBINFO. These include subject mappers for efficiently handling subjects, service disciplines for controlling the interaction with servers, and protocol engines for implementing reliable communication protocols. TIBINFO provides an interface for setting properties of these components. Hence, by setting the appropriate properties, one can specify, for example, the behavior of the subject mapper through the

TIBINFO interface. Since these properties are in configuration files, configuration and site dependent parameters can be supported for the above components through TIBINFO.

In the future, the property definitions for TIBINFO and for the underlying components may augmented to support enhancements. This use of properties yields flexibility and extensibility within the confines of a stable functional interface.

### 4.3 Description

The TIBINFO interface is high-level and easy to use. Published data can be a form or an uninterpreted byte string. Messages can be received either in a synchronous fashion, or in an asynchronous fashion that is suitable for event-driven programming. The following functions are sufficient to write sophisticated consumers using event-driven programming.

```
Tib_stream    *tib_consume_create(property-list, TIB_EOP)
```

Creates a TIBINFO stream that supports multiple subscriptions via the "subscribe" function. The property__list is a (possibly empty) list of property value pairs, as illustrated by
tib__consume__create(TIB__PROP__MSGHANDLER, my__handler,
TIB__PROP__ERRHANDLER, my__err__handler, TIB__EOP);

Valid properties are defined below. TIB__EOP is a literal signaling the end of the property list.

```
void tib_destroy(stream)

Tib_stream    *stream;
```

Reclaims resources used by the specified stream.

```
Tib_errorcode tib_subscribe(stream, subject, clientdata)

Tib_stream      *stream;
Tib_subject     *subject;
caddr_t         clientdata;
```

Informs the TIB that the client application is interesting in messages having the indicated subject. If stream has an associated "message-handler," then it will be called whenever a message satisfying the subscription arrives. Qualifying messages are delivered on a first-in/first-out basis. The value of clientdata is returned in every message satisfying the subscription subject. Note that multiple subscriptions to the same subject on the same stream are undefined.

```
void tib_cancel(stream)

Tib_stream    *stream;
```

Cancels the client application's subscription to the specified subject.

```
void my_message_handler(stream,msg)

Tib_stream      *stream;
Tib_message     *message;
```

This is the "callback" function that was registered with the stream. forms are returned unpacked. The function can reference the entire message structure through the macros described below.

The following functions are sufficient to write producers. Two publishing functions are provided to support the different data types that can be transmitted through the TIB-INFO interface.

tib__publish__create(property-list, TIB__EOP)

Is used to create an TIBINFO stream for publishing records. The property__list is a (possibly empty) list of property-value pairs, as illustrated by

tib__publish__create(TIB__PROP__ERRHANDLER,my__handler,TIB__EOP);

Valid properties are defined below. TIB__EOP is a constant signaling the end of the property list.

```
tib_destroy(stream)

Tib_stream     stream;
```

Reclaims resources used by the specified stream.

```
Tib_errorcode tib_publish_form(stream, subject, form)

Tib_stream      *stream;
Tib_subject     *subject;
Form            form;
```

Accepts a single, unpacked form, packs it, and publishes it.

```
Tib_errorcode tib_publish_buffer(stream, subject, length,
form)

Tib_stream      *stream;
Tib_subject     *subject;
short           length;
Form            form;
```

Accepts a byte buffer of specified length and publishes it.

The remaining functions are control functions that apply to both the consume and the publish side.

void Tib__batch()

This may be used prior to initiating multiple subscriptions. It informs the TIB library that it can delay acting on the subscriptions until a tib__unbatch is seen. This allows the TIB library to attempt to optimize the execution of requests. Note that no guarantees are made about the ordering or timing of "batched" request. In particular, (i) requests may be executed prior to the receipt of the tib__unbatch function, and (ii) the effects of changing properties in the middle of a batched sequence of requests is ur defined. Batch and unbatch requests may be nested. (Note that the use of tib__batch is completely optional and it does not change the semantics of a correct program.)

```
Tib_errorcode tib_stream_set(stream, property, value)

Tib_stream      *stream;
Tib_property    *property;
caddr_t         value;
```

Used to change the dynamically settable properties of a stream. These properties are described below. Note that some properties can only be set prior to stream creation (via tib__default__set) or at stream creation.

```
caddr_t tib_stream_get(stream, property)

Tib_stream          *stream;
Tib_property    *property;
```

Used to retrieve the current value of the specified property.

```
Tib_errorcode tib_default_set( property, value)

Tib_stream      *stream;
Tib_property    *property;
caddr_t         value;
```

Used to change the initial properties of a stream. During stream creation, the default values are used as initial values in the new stream whenever a property value is not explicitly specified in the creation argument list.

```
Tib_errorcode tib_default_get( property)

Tib_stream      *stream;
Tib_property    *property;
```

Used to retrieve the default value of the specified property.

tib_unbatch()

Informs TIBINFO stop "batching" functions and to execute any outstanding ones.

TIBINFO Attributes

The properties defined by TIBINFO and their allowable values are listed below and are described in detail in the appropriate "man" pages. The last grouping of properties allow the programmer to send default property values and hints to the underlying system components-specifically, the network protocol engines, the TIB subject mapper, and various service disciplines.

| | |
|---|---|
| TIB_PROP_CFILE | cfile-handle |
| TIB_PROP_CLIENTDATA | pointer |
| TIB_PROP_ERRHANDLER | error-handler-routine |
| TIB_PROP_LASTMSG | tib_message pointer |
| TIB_PROP_MSGHANDLER | message-handler-routine |
| TIB_PROP_NETWORK | protocol-engine-property-list |
| TIB_PROP_NETWORK_CFILE | protocol-engine-property-cfile |
| TIB_PROP_SERVICE | service-discipline-property-list |
| TIB_PROP_SERVICE_CFILE | service-discipline-property-cfile |
| TIB_PROP_SUBJECT | subject-property-list |
| TIB_PROP_SUBJECT_CFILE | subject-property-cfile |

TIBINFO Message Structure

The component information of a TIBINFO message can be accessed through the following macros:
tib_msg_clientdata(msg)
tib_msg_subject(msg)
tib_msg_size(msg)
tib_msg_value(msg)
The following macros return TRUE (1) or FALSE (0):
tib_msg_is_buffer(msg)
tib_msg_is_form(msg)

## 5. TIB Forms

### 5.1 Introduction

The Forms package provides the tools to create and manipulate self-describing data objects, e.g., forms. Forms have sufficient expressiveness, flexibility and efficiency to describe all data exchanged between the different TIB applications, and also between the main software modules of each application.

The Forms package provides its clients with one data abstraction. Hence, the software that uses the Forms package deal with only one data abstraction, as opposed to a data abstraction for each different type of data that is exchanged. Using forms as the only way to exchange user data, facilitates (i) the integration of new software modules that communicate with other software modules, and (ii) modular enhancement of existing data formats without the need to modify the underlying code. This results in software that is easier to understand, extend, and maintain.

Forms are the principal shared objects in the TIB communication infrastructure and applications; consequently, one of the most important abstractions in the TIB.

The primary objective in designing the forms package were:

o Extensibility - It is desirable to be able to change the definition of a form class without recompiling the

application, and to be able introduce new classes of forms into the system.

o Maintainability - Form-class definition changes may affect many workstations; such changes must be propagated systematically.

o Expressiveness - Forms must be capable of describing complex objects; therefore, the form package should support many basic types such as integer, real, string, etc. and also sequences of these types.

o Efficiency - Forms should be the most common object used for sending information between processes-both for processes on the same workstation and for processes on different workstations. Hence, forms should be designed to allow the communication infrastructure to send information efficiently.

Note that our use of the term "form" differs from the standard use of the term in database systems and so-called "forms management systems." In those systems, a "form" is a format for displaying a database or file record. (Typically, in such systems, a user brings up a form and paints a database record into the form.)

Our notion of a form is more fundamental, akin to such basic notions as record or array. Our notion takes its meaning from the original meaning of the Latin root word forma . Borrowing from Webster: "The shape and structure of something as distinguished from its material". Forms can be instantiated, operated on, passed as arguments, sent on a network, stored in files and databases. Their contents can also be displayed in many different formats. "templates" can be used to specify how a form is to be displayed. A single form (more precisely, a form class) can have many "templates" since it may need to be displayed in many different ways. Different kinds of users may, for example, desire different formats for displaying a form.

### 5.2 Description

Forms are self-describing data objects. Each form contains a reference to its formclass, which completely describes the form. Forms also contains metadata that enables the form package to perform most operations without accessing the related formclass definition.

Each form is a member of a specific form class. All forms within a class have the same fields and field's labels (in fact, all defining attributes are identical among the forms of a specific class). Each form class is named and two classes are considered to be distinct if they have distinct names (even though the classes may have identical definitions). Although the forms software does not assign any special meaning or processing support to particular form names, the applications using it might. (In fact, it is expected that certain form naming conventions will be established.)

There are two main classification of forms: primitive versus constructed forms, and fixed length versus variable size forms.

Primitive forms are used to represent primitive data types such as integers, float, strings, etc. Primitive forms contain metadata, in the form header information header and the data of the appropriate type, such as integer, string, etc.

Constructed forms contain sub-forms. A constructed form contains other forms, which in turn can contain subforms.

Fixed length forms are simply forms of a fixed length, e.g., all the forms of a fixed length class occupy the same number of bytes. An example for a fixed length primitive form is the integer form class; integer forms always take 6 bytes, (2 bytes for the form header and 4 bytes for the integer data).

Variable size forms contain variable size data: variable size, primitive forms contain variable size data, such as variable length string; variable size, constructed forms contain a variable number of subforms of a single class. Such forms are similar to an array of elements of the same type.

### 5.3 Class Identifiers

When a class is defined it is assigned an identifier. This identifier is part of each of the class's form instance, and is used to identify the form's class. This identifier is in addition to its name. Class identifiers must be unique within their context of use. Class identifiers are 2 bytes long; bit 15 is set if the class is fixed length and cleared otherwise; bit 14 is set if the class is primitive and cleared otherwise;

### 5.4 Assignment semantics

To assign and retrieve values of a form (or a form sequence), "copy" semantics is used. Assigning a value to a form (form field or a sequence element) copies the value of the form to the assigned location-it does not point to the given value.

Clients that are interested in pointer semantics should use forms of the basic type Form Pointer and the function Form__set__data__pointer. Forms of type Form Pointer contain only a pointer to a form; hence, pointer semantics is used for assignment. Note that the C programming language supports pointer semantics for array assignment.

### 5.5 Referencing a Form Field

A sub-form or field of a constructed form can be accessed by its field name or by its field identifier (the latter is generated by the Forms package). The name of a subform that is not a direct descendent of a given form is the path name of all the fields that contain the requested subform, separated by dot. Note that this is similar to the naming convention of the C language records.

A field identifier can be retrieved given the field's name and using the function Form-class__get__field__id. The direct fields of a form can be traversed by using Form__field__id__first to get the identifier of the first field, and then by subsequently calling Form__field__id__next to get the identifiers of each of the next fields.

Accessing a field by its name is convenient; accessing it by its identifier is fast. Most of the Forms package function references a form field by the field's identifier and not by the field's name.

### 5.6 Form-class Definition Language

Form classes are specified using the "form-class definition language," which is illustrated below. Even complex forms can be described within the simple language features depicted below. However, the big attraction of a formal language is that it provides an extensional framework: by adding new language constructs the descriptive power of the language can be greatly enhanced without rendering previous descriptions incompatible.

A specification of a form class includes the specification of some class attributes, such as the class name, and a list of specifications for each of the class's fields. Three examples are now illustrated:

```
{
short {
          IS_FIXED                    true;
          IS_PRIMITIVE                true;
          DATA_SIZE                   2;
          DATA_TYPE                   9;
          }
short_array {       # A variable size class of shorts.
          IS_FIXED                    false;
          FIELDS  {
          {
               FIELD_CLASS_NAME short;
          }
          }}
```

```
example_class {
            IS_FIXED                true;
            FIELDS  {
            first  {
                 FIELD_CLASS_NAME short;
            }
            second {
                 FIELD_CLASS_NAME short_array;
            }
            third {
                 FIELD_CLASS_NAME string_30;
            }
            fourth {
                 FIELD_CLASS_NAME integer;
            }
            }

}}
```

To specify a class, the class's name, a statement of fixed or variable size, and a list of fields must be given. For primitive classes the data type and size must also be specified. All the other attributes may be left unspecified, and defaults will be applied. To define a class field, either the field class name or id must be specify.

The form-class attributes that can be specified are:

o The class name.

o CLASS__ID - The unique short integer identifier of the class. Defaults to a package specified value.

o IS__FIXED - Specifies whether its a fixed or variable size class. Expects a boolean value. This is a required attribute.

o IS__PRIMITIVE - Specifies whether its a primitive or constructed class. Expects a boolean value. Defaults to False.

o FIELDS__NUM - An integer specifying the initial number of fields in the form. Defaults to the number of specified fields.

o DATA__TYPE - An integer, specified by the clients, that indicates what is the type of the data. Used mainly in defining primitive classes. It does not have default value.

o DATA__SIZE - The size of the forms data portion. Used mainly in defining primitive classes. It does not have default value.

o FIELDS - Indicates the beginning of the class's fields definitions.

The field attributes that can be specified are:

o The class field name.

o FIELD__CLASS__ID - The class id for the forms to reside in the field. Note that the class name can be used for the same purpose.

o FIELD__CLASS__NAME - The class name for the forms to reside in the field.

Here is an example of the definition of three classes:

Note that variable length forms contains fields of a single class. "integer" and "string__30", used in the above examples, are two primitive classes that are defined within the Formclass package itself.

**5.7 Form Classes are Forms**

Form classes are implemented as forms. This means functions that accept forms as an argument also accept form classes. Some of the more useful functions on form classes are:
o Form_pack, Form_unpack - Can be used to pack and unpack form classes.
o Form_copy - Can be used to copy form classes.
o Form_show - Can be used to print form classes.

### 5.8 Types

**typedef Formclass**

A form-class handle.

**typedef Formclass_id**

A form-class identifier.

**typedef Formclass_attr**

A form-class attribute type. Supported attributes are:
o FORMCLASS_SIZE - The size of the class form instances.
o FORMCLASS_NAME - The class name.
o FORMCLASS_ID - A two byte long unique identifier.
o FORMCLASS_FIELDS_NUM - The number of (direct) fields in the class. This is applicable only for fixed length classes. The number of fields in a variable length class is different for each instance; hence, is kept in each form instance.
o FORMCLASS_INSTANCES_NUM - The number of form instances of the given class.
o FORMCLASS_IS_FIXED - True if its a fixed length form, False if its a variable length form.
o FORMCLASS_IS_PRIMITIVE - True if its a form of primitive type, False if its a constructed form, .i.e. the form has sub forms.
o FORMCLASS_DATA_TYPE - This field value is assigned by the user of the forms a to identify the data type of primitive forms. In our current application we use the types constants as defined by the enumerated type Form_data_type, in the file forms.h.
o FORMCLASS_DATA_SIZE - This field contains the data size, in bytes, of primitive forms. For instance, the data size of the primitive class Short is two. Because it contains the C type short, which is kept in two bytes.

**typedef Formclass_field_attr**

A form-class field attribute type. Supported form class field attributes are:
o FORMCLASS_FIELD_NAME - The name of the class field.
o FORMCLASS_FIELD_CLASS_ID - The class id of the field's form.

**typedef Form**

A form handle.

**typedef Form_field_id**

An identifier for a form's field. It can identifies fields in any level of a form. A field identifier can be retrieved form a field name, using the function Form-class_get_field_name. A form_field_id is manipulated by the functions:

Form__field__id__first and Form__field__id__next.

**typedef Form__attr**

A form attribute type. Supported form attributes are:
o FORM__CLASS__ID - The form's class identifier.
o FORM__DATA__SIZE - The size of the form's data. Available only for constructed, not primitive, forms or for primitive forms that are of variable size. For fixed length primitive forms this attribute is available via the form class.
o FORM__FIELDS__NUM - The number of fields in the given form. Available only for constructed, not primitive forms. For primitive forms this attribute is available via the form class.

**typedef Form__data**

The type of the data that is kept in primitive forms.

**typedef Form__pack__format**

Describes the possible form packing types. Supported packing formats are:
o FORM__PACK__LIGHT - Light packing, used mainly for inter process communication between processes on the same machine. It is more efficient then other types of packing. Light packing consists of serializing the given form, but it does not translates the form data into machine independent format.
o FORM__PACK__XDR - Serialize the form while translating the data into a machine-independent format. The machine-independent format used is Sun's XDR.

**5.9 Procedural Interface to the Forms-class Package**

The formclass package is responsible for creating and manipulating forms classes. The forms package uses these descriptions to create and manipulate instances of given form classes. An instance of a form class is called, not surprisingly, a form.

**Formclass__create**

Create a class handle according to the given argument list. If the attribute CLASS__CFILE is specified it should be followed by a cfile handle and a path__name. In that case formclass__create locates the specification for the form class in the specified configuration file. The specification is compiled into an internal data structure for use by the forms package.

Formclass__create returns a pointer to the class data structure. If there are syntax errors in the class description file the function sets the error message flag and returns NULL.

**Formclass__destroy**

The class description specified by the given class handle is dismantled and the storage is reclaimed. If there are live instances of the class then the class is not destroyed and the error value is updated to "FORMCLASS__ERR__NON__ZERO__INSTANCES__NUM".

**Formclass__get**

Given a handle to a form class and an attribute of a class (e.g. one of the attributes of the type Formclass__attr) Formclass__get returns the value of the attribute. Given an unknown attribute the error value is updated to "FORMCLASS__ERR__UNKNOWN__ATTRIBUTE".

**Formclass_get_handle_by_id**

Given a forms-class id, Formclass_get_handle_by_id returns the handle to the appropriate class descriptor. If the requested class id is not known Formclass_get_handle_by_id returns NULL, but does not set the error flag.

**Formclass_get_handle_by_name**

Given a forms-class name, Formclass_get_handle_by_name returns the handle to the appropriate class descriptor. If the requested class name is not known Formclass_get_handle_by_name returns NULL, but does not set the error flag.

**Formclass_get_field_id**

Given a handle to a form class and a field name this function returns the form id, which is used for a fast access to the form. If the given field name does not exist, it updated the error variable to FORMCLASS_ERR_UNKNOWN_FIELD_NAME.

**Formclass_field_get**

Returns the value of the requested field's attribute. If an illegal id is given this procedure, it updated the error variable to FORMCLASS_ERR_UNKNOWN_FIELD_ID.

**Formclass_iserr**

Returns TRUE if Formclass error flag is turned on, FALSE otherwise.

**Formclass_errno**

Returns the formclass error number. If no error, it returns FORMCLASS_OK. For a list of supported error values see the file formclass.h.

**5.10 The Forms Package**

**Form_create**

Generate a form (i.e., an instance) of the form class specified by the parameter and return a handle to the created form.

**Form_destroy**

The specified form is "destroyed" by reclaiming its storage.

**Form_get**

Given a handle to a form and a valid attribute (e.g. one of the values of the enumerated type Form_attr) Form_get returns the value of the requested attribute.

The attribute FORM_DATA_SIZE is supported only for variable siz forms. For fixed size form this information is kept in the class description and is not kept with each form instance. Requiring the

FORM_DATA_SIZE from a fixed length form will set the error flag to FORM_ERR_NO_SIZE_ATTR_FOR_FIXED_LENGTH_FORM.

The attribute FORM_FIELDS_NUM is supported only for constructed forms. Requiring the FORM_FIELDS_NUM from a primitive form will set the error flag to FORM_ERR_ILLEGAL_ATTR_FOR_PRIMITIVE_FORM.

If the given attribute is not known the error flag is set to FORM_ERR_UNKNOWN_ATTR. When the error flag is set differently, then FORM_OK Form_get returns NULL.

**Form_set_data**

Sets the form's data value to the given value. The given data argument is assumed to be a pointer to the data, e.g., a pointer to an integer or a pointer to a date structure. However for strings we expect a pointer to a character.

Note that we use Copy semantics for assignments.

**Form_get_data**

Return a pointer to form's data portion. In case of a form of a primitive class the data is the an actual value of the form's type. If the form is not of a primitive class, i.e., it has a non zero number of fields, then the form's value is a handle to the form's sequence of fields.

Warning, the returned handle points to the form s data structure and should not be altered. If the returned value is to be modified is should be copied to a private memory.

**Form_set_data_pointer**

Given a variable size form, Form_set_data_pointer assigns the given pointer to the points to the forms data portion. Form_set_data_pointer provide a copy operation with pointer semantics, as opposed to copy semantics.

If the given form is a fixed length form then the error flag is set to FORM_ERR_CANT_ASSIGN_POINTER_TO_FIXED_FORM.

**Form_field_set_data**

This is a convenient routine that is equal to calling Form_field_get and then using the retrieved form to call Form_set_data. More precisely: form_field_set_data(form, field_id, form_data, size) = = form_set_data(form_field_get(form, field_id), form_data, size), plus some error checking.

**Form_field_get_data**

Note that we use Copy semantics for assignments.

This is a convenient routine that is equal to calling Form_field_get and then using the retrieved form to call Form_get_data. More precisely: form_field_get_data(form, field_id, form_data, size) = = form_get_data(form_field_get(form, field_id), form_data, size) plus some error checking.

Warning, the returned handle points to the form's data structure and should not be altered. If the returned value is to be modified is should be copied to a private memory.

**form_field_id_first**

Form_field_id_first sets the given field_id to identify the first direct field of the given form handle.

Note that the memory for the given field_id should be allocated (and freed) by the clients of the forms package and not by the forms package.

**form_field_id_next**

Form_field_id_first sets the given field_id to identify the next direct field of the given form handle. Calls to Form_field_id_next must be preceded with a call to Form_field_id first.

Note that the memory for the given field_id should be allocated (and freed) by the clients of the forms package and not by the forms package.

**Form_field_set**

Sets the given form or form sequence as the given form field value. Note that we use Copy semantics for assignments.

When a nonexistent field id is given then the error flag is set to FORM_ERR_ILLEGAL_ID.

**Form_field_get**

Return's a handle to the value of the requested field. The returned value is either a handle to a form or to a form sequence.

Warning, the returned handle points to the form's data structure and should not be altered. If the returned value is to be modified is should be copied to a private memory, using the Form_copy function.

When a nonexistent field id is given, then the error flag is set to FORM_ERR_ILLEGAL_ID and Form_field_get returns NULL.

**Form_field_append**

Form_field_append appends the given, append_form argument to the end of the base_form form sequence. Form_field_append returns the id of the appended new field.

**Form_field_delete**

Form_field_delete deletes the given field from the given base_form.

If a non existing field id is given then the error flag is set to FORM_ERR_ILLEGAL_ID and Form_field_delete returns NULL.

**Form_pack**

Form_pack returns a pointer to a byte stream that contains the packed form, packed according to the requested format and type.

If the required packed type is FORM_PACK_LIGHT then Form_pack serializes the form, but the forms data is not translated to a machine-independent representa tion. Hence a lightly packaged form is suitable to transmit between processes on the same machine.

If the required packed type is FORM_PACK_XDR then Form_pack serializes the form and also translates the form representation to a machine-independent representation, which is Sun's XDR. Hence form packed by an XDR format are suitable for transmitting on a network across machine boundaries.

Formclass.h. are implemented as forms, hence Form_pack can be used to pack form classes as well as forms.

**Form_unpack**

Given an external representation of the form, create a form instance according to the given class and unpack the external representation into the instance.

Form classes are implemented as forms, hence Form_unpack can be used to unpack form classes as well as forms.

**Form_copy**

Copy the values of the source form into the destination form. If the forms are of different classes no copying is performed and the error value is updated to FORM_ERR_ILLEGAL_CLASS.

Formclasses are implemented as forms, hence Form_copy can be used to copy form classes as well as forms.

**Form_show**

Return an ASCII string containing the list of field names and associated values for indicated fields. The string is suitable for displaying on a terminal or printing (e.g., it will contain new-line characters). The returned string is allocated by the function and need to be freed by the user. (This is function is very useful in debugging.)

Formclasses are implemented as forms, hence Form_show can be used to print form classes as well as forms.

**Form_iserr**

Returns TRUE if the error flag is set, FALSE otherwise.

**Form_errno**

Returns the formclass error number. If no error, it returns FORMCLASS_OK. The possible error values are defined in the file forms.h.

GLOSSARY

There follows a list of definitions of some of the words and phrases used to describe the invention.

Format or Type:

The data representation and data organization of a structural data record, i.e., form.

Foreign:

A computer or software process which uses a different format of data record than the format data record of another computer or software process.

Form:

A data record or data object which is self-describing in its structure by virtue of inclusion of fields containing class descriptor numbers which correspond to class descriptors, or class definitions. These class descriptors describe a class of form the instances of which all have the same internal representation, the same organization and the same semantic information. This means that all instances, i.e., occurrences, of forms of this class have the same number of fields of the same name and the data in corresponding fields have the same representation and each corresponding field means the same thing. Forms can be either primitive or constructed. A form is primitive if it stores only a single unit of data. A form is constructed if it has multiple internal components called fields. Each field is itself a form which may be either primitive or constructed. Each field may store data or the class_id, i.e., the class number, of another form.

Class/Class Descriptor/Class Definition:

A definition of the structure and organization of a particular group of data records or "forms" all of which have the same internal representation, the same organization and the same semantic information. A class descriptor is a data record or "object" in memory that stores the data which defines all these parameters of the class definition. The Class is the name of the group of forms and the Class Definition is the information about the group's common characteristics. Classes can be either primitive or constructed. A primitive class contains a class name that uniquely identifies the class (this name has associated with it a class number or class_id) and a specification of the representation of a single data value. The specification of the representation uses well known primitives that the host computer and client applications understand such as string_20 ASCII, floating point, integer, string_20 EBCDIC etc. A constructed class definition includes a unique name and defines by name and content multiple fields that are found in this kind of form. The class definition specifies the organization and semantics or the form by specifying field names. The field names give meaning to the fields. Each field is specified by giving a field name and the form class of its data since each field is itself a form. A field can be a list of forms of the same class instead of a single form. A constructed class definition contains no actual data although a class descriptor does in the form of data that defines the organization and semantics of this kind of form. All actual data that define instances of forms is stored in forms of primitive classes and the type of data stored in primitive classes is specified in the class definition of the primitive class. For example, the primitive class named "Age" has one field of type integer_3 which is defined in the class definition for the age class of forms. Instances of forms of this class contain 3 digit integer values.

Field:

One component (?) in an instance of a form which may have one or more components (?), each named differently and each meaning a different thing. Fields are "primitive" if they contain actual data and are "constructed" if they contain other forms, i.e., groupings of other fields. A data record or form which has at least one field which contains another form is said to be "nested". The second form recorded in the constructed field of a first form has its own fields which may also be primitive or constructed. Thus, infinitely complex layers of nesting may occur.

Process:

An instance of a software program or module in execution on a computer.

Semantic Information:

With respect to forms, the names and meanings of the various fields in a form.

Nested:

A data structure comprised of data records having multiple fields each of which may contain other data records themselves containing multiple fields.

Primitive Field:

A field of a form or data record which stores actual data.

Constructed Field:

A field which contains another form or data record.

Format Operation:

An operation to convert a form from one format to another format.

Semantic-Dependent Operation:

An operation requiring access to at least the semantic information of the class definition for a particular form to supply data from that form to some requesting process.

Application:

A software program that runs on a computer other than the operating system programs.

Decoupling:

Freeing a process, software module or application from the need to know the communication protocols, data formats and locations of all other processes, computers and networks with which data is to be interchanged.

Class:

A definition of a group of forms wherein all forms in the class have the same format and the same semantics.

Interface:

A library of software programs or modules which can be invoked by an application or another module of the interface which provide support functions for carrying out some task. In the case of the invention at hand, the communication interface provides a library of programs which implement the desired decoupling between foreign processes and computers to allow simplified programming of applica tions for exchanging data with foreign processes and computers.

Subscribe Request:

A request for data regarding a particular subject which does not specify the source server or servers, process or processes or the location of same from which the data regarding this subject may be obtained.

Service Record:

A record containing fields describing the important characteristics of an application providing the specified service. Server Process : An application process that supplies the functions of data specified by a particular service, such as Telerate, Dow Jones News Service, etc.

Service Discipline or Service Protocol:

The protocol for communication with a particular server process, application, local area network.

Client Application:

An application linked to the libraries of the communication interface according to the teachings of the invention or otherwise linked to a service.

Transport Layer:

A layer of the standard ISO model for networks between computers to which the communication interface of the invention is linked.

Transport-layer Protocol:

The particular communication protocol or discipline implemented on a particular network.

Service:

A meaningful set of functions or data which an application can export for use by client applications. In other words, a service is a general class of applications which do a particular thing, e.g., applications supplying Dow Jones News information.

Service Instance:

A process running on a particular computer and which is capable of providing the specified service (also sometimes called a server process).

Server:

A computer running a particular process to do something such as supply files stored in bulk storage or raw data from an information source such as Telerate to a network or another computer/workstation for distribution to other processes coupled to the server.

Subject Space:

A hierarchical set of subject categories.

Subject Domain:

A set of subject categories (see also subject space).

Class Definition:

The specification of a form class.

Class Descriptor:

A memory object which stores the formclass definition. In the class manager, it is stored as a form. On disk, it is stored as an ASCII string. Basically, it is a particular representation or format for a class definition. It can be an ASCII file or a form type of representation. When the class manager does not have a class descriptor it needs, it asks the foreign application that created the class definition for the class descriptor. It then receives a class descriptor in the format of a form as generated by the foreign application. Alternatively, the class manager searches a file or files identified to it by the application requesting the

semantic-dependent operation or identified in records maintained by the class manager. The class definitions stored in these files are in ASCII text format. The class manager then converts the ASCII text so found to a class descriptor in the format of a native form by parsing the ASCII text into the various field names and specifications for the contents of each field.

Native Format/Form:

The format of a form or the form structure native to an application and its host computer.

ID:

A unique identifier for a form, record, class, memory object etc. The class numbers assigned the classes in this patent specification are examples of ID's.

Handle:

A pointer to an object, record, file, class descriptor, form etc. This pointer essentially defines an access path to the object. Absolute, relative and offset addresses are examples of handles.

Class Data Structure:

All the data stored in a class manager regarding a particular class. The class descriptor is the most important part of this data structure, but there may be more information also.

Configuration File:

A file that stores data that describes the properties and attributes or parameters of the various software components, records and forms in use.

Attribute of a Form Class:

A property of form class such as whether the class is primitive or constructed. Size is another attribute.

## Claims

1. A communication interface for decoupling a first computer program or application's natural data record or form format from the foreign data record or form format of a second computer program or application with which data records are to be exchanged, comprising:
first means coupled to said first computer program or application for creating and manipulating self-describing data records or forms which contain both data and class identification data corresponding to one or more class definitions that define the names and organization of fields within said form as well as the format for data representation within said fields;
second means coupled to said first means for converting the format of a form in a format native to said first application to be transmitted to said second application to the format of said second application.

2. A communication interface for decoupling a transmitting application's natural data record or form format from the foreign data record or form format of a receiving application, for facilitating the transfer of forms from said transmitting application to said receiving application via a network, comprising:
first means coupled to said transmitting application for creating, storing, recalling, manipulating and destroying self-describing data objects called forms which contain both data and class identification data corresponding to one or more class definitions that define the names and organization of fields within said form as well as the format for data representation within said fields, said form being created in the natural

form format of said transmitting application;
second means coupled to said receiving application for creating, storing, recalling, manipulating and destroyimg self-describing data objects called forms which contain both data and class identification data corresponding to one or more class definitions that define the names and organization of fields within said form as well as the format for data representation within said fields, said form being created in the natural form format of said application which is a foreign form format relative to the natural format used by said transmitting application;
third means coupled to said network and to said first means for converting the format of a form in a format native to the transmitting application to be transmitted to a foreign application to the format of said network and for transmitting said form over said network;
fourth means coupled to said second means and to said network for receiving said transmitted form to the format native to said receiving application and for supplying said form to said receiving application.
3. The apparatus of claim 2 wherein said third means includes one or more target format-specific tables each containing records mapping particular from formats to selected to formats, and further comprises a procedures-mapping table containing records that map particular from-to format pairs to particular conversion programs which convert primitive class forms in the from format to corresponding primitive class forms in the to format, said third means further comprising means for receiving a request for a format conversion operation, said request including a from format and a to format and the address of a form which may be either primitive or constructed and which contains one or more fields, each said field being a form and being associated with a class identifier uniquely identifying the class of said form, each said field storing a value if said field is a form of a primitive class or, if said field is a form of a constructed class, store other forms which themselves have fields which store values or other forms, said form to be converted from the from format to the to format, and further comprising means in said third means for searching through the fields of said form until a primitive form is found and for using the class identifier associated with said primitive field and accessing the appropriated target format-specific table and finding an entry with a matching entry in the from format portion of said entry and determining the associated to format class identifier for said from format class identifier, and further comprising means for accessing said procedures-mapping table and locating an entry therein with a matching from-to format pair and determining the name of the appropriate format conversion program listed in said matching entry, and further comprising means for calling and executing said format conversion program to convert the from format of said primitive field to the appropriate to format and for storing the results of the conversion, and further comprising means for further searching said form to be converted to find the next field storing a primitive form and for converting said field to the to format listed in the appropriate target specific table using the conversion program listed for the from-to format pair of said field in said procedures-mapping table and for storing the result and for repeating the search, table access and conversion functions for each field in said form until all fields have been converted.
4. A communication interface for decoupling one application's data format from the data format of anoth r application with which data is to be exchanged, comprising:
means coupled to each said application for creating and managing forms containing data pertinent to the corresponding application in the format native to each said application, each said form containing one or more class identifiers corresponding to one or more class definitions the give the name, data type and organization of the fields of each form instance of the class to which said form belongs and wherein each said field may contain data or another subform of another class, each said subform storing one or more class identifiers and the field names, data type and organization of the fields of said subform, and wherein each said field of said subform may contain data or another sub-subform and so on for a selectable number of levels of nesting; and
means for converting the format of a form to be transmitted to another application to all formats necessary to accomplish the transmission including a final conversion to the format rendering the form suitable for use by the receiving application.
5. A communication interface for decoupling a transmitting application's natural form format from the foreign form format of a receiving application, for facilitating the transfer of data records called forms from said transmitting application to said receiving application via a network, comprising:
first means coupled to said transmitting application for creating, storing, recalling, manipulating and destroying self-describing data objects called forms which contain both data and class identification data corresponding to one or more class definitions that define the names and organization of fields within said form as well as the format for data representation within said fields, said form being created in the natural form format of said transmitting application;
second means coupled to said receiving application for creating, storing, recalling, manipulating and

destroying self-describing data objects called forms which contain both data and class identification data cor responding to one or more class definitions that define the names and organization of fields within said form as well as the format for data representation within said fields, said form being created in the natural form format of said application which is a foreign form format relative to the natural format used by said transmitting application;
third means coupled to said first means for storing said class definitions for form classes of forms created and used by said first means and the locations of files in which class definitions for form classes of forms created and used by said second means can be found;
fourth means coupled to said second means for storing said class definitions for form classes of forms created and used by said second means and the locations of files in which class definitions for form classes of forms created and used by said first means can be found;
fifth means in said third means for receiving a request to locate a particular field name in a form and for accessing one or more class definitions identified by class identifiers stored in said form and searching said class definitions for a field name which matches the name of the field in the original request and returning a pointer address which can be used to find the value stored in the named field and for receiving a request to obtain the data stored in the field named in the original request and accessing said form and obtaining the data in said field using said pointer address;
sixth means in said fourth means for receiving a request to locate a particular field name in a form and for accessing one or more class definitions identified by class identifiers stored in said form and searching said class definitions for a field name which matches the name of the field in the original request and returning a pointer address which can be used to find the value stored in the named field and for receiving a request to obtain the data stored in the field named in the original request and accessing said form and obtaining the data in said field using said pointer address.

6. A communication interface for decoupling a first application's natural form format from the foreign form format of a second application, comprising:
first means coupled to said first application for creating and manipulating self-describing data objects called forms which contain both data and class identification data corresponding to one or more class definitions that define the names and organization of fields within said form as well as the format for data representation within said fields; and
second means coupled to said first means for receiving requests by said first application to access the data in any selected field of a foreign form used by said second application and accessing the class definition defining the field names and organization of said form used by said second application and locating the named field which matches the field name given in said request and returning a pointer address to said field and accessing said form and using said pointer address to obtain and return to said first application the data stored in the field named in the original request.

7. The apparatus of claim 6 further comprising means coupled to said first means for converting the format of a form in a format native to said first application to be transmitted to said second application to the format of said foreign application using said class identification data stored in said form and without accessing the class definition defining the semantic data and organization of the fields of said form.

8. An apparatus for implementing the exchange of information between software modules which may or may not have the same format in terms of data representation and organization of the data for data records called forms where an instance of a form is actual data in the data representation and organization defined by the form and where the software modules may or may not reside in the same computer and may or may not reside in the same software process and where the software modules may or may not use data records having the same semantic information for various fields of data where semantic information defines the names of the various fields of data, comprising:
first means linked to one or more of said software modules and comprising a computer and a library of software programs executed by said computer for creating, storing, retrieving and reading class descriptors, said class descriptors being data records which contain data defining both semantic information regarding the names of each field of data in an instance of the form class to which the class descriptor applies and format information regarding the data representation and organization of the fields of data in instances of forms of the class to which said class descriptor corresponds;
second means linked to one or more of said modules and comprising a computer and a library of software programs executed by said computer for creating, storing, retrieving and reading instances of one or more class of forms, each said instance containing both format data regarding the data representation and organization of the data in said form as well as the actual data comprising the instance of said form;
third means linked to one or more of said modules and comprising a computer and a library of software programs for providing an interface between said software modules and said first and second means such

that said software modules can usefully exchange instances of forms by calling appropriate software programs in said first and second means to cause said first and second means to combine to translate, manipulate and interpret information from one of said modules and send said information to another said software module as an instance of a form in such a manner that said exchanged information has meaning to and can be used by said other module despite format and semantic differences between said software modules.

9. An apparatus as defined in claim 8 wherein said third means includes means for receiving a request from a module to obtain any of said class descriptors and for causing said first means to start a search for the desired class descriptor, and wherein said first means includes means for checking a stored list of the file locations for storage of class definitions and for retrieving the stored data for said desired class definition if said class definition is found in any of said files and for converting said class definition to a form and, if not so found, for requesting the class definition from a first means which has information regarding where the desired class definition is stored.

10. An apparatus for providing a communication facility between first and second computer programs each of which use data records having different structures and data representation formats, comprising:

means for creating nested data records for each of said first and second computer programs having the structures and data representation formats native to each of said first and second programs, said data records being nested in the sense that any one data record may have one or more fields that contain other data records and so on for any number of levels of nesting, each data record be ing assigned to a class having associated therewith a class identifier and each instance of a data record including the class identifiers of all the classes for all data records which, taken together, comprise the data record;

means for facilitating transfers of data records between said first and second computer programs by automatically translating the format of data records from the format of the sending computer program to the format of the receiving computer program without the need for processing by either said first or second computer program.

11. The apparatus of claim 10 further comprising means for facilitating the extraction by said first computer program of data from a data record in the format used by said second computer program by receiving the path name for the form instance of interest and the field name for the field in said instance of said data record containing the desired data and automatically, without processing by said first computer program, locating the class definition for the class of data record to which said instance belongs and for locating in said class definition the field named in the request and generating a pointer address indicating where in instances of said class of data records the data values stored in the named field may be found and accessing the desired data value from the instance of interest using said pointer address.

12. The apparatus of claim 11 further comprising subject-based addressing means coupled to said first computer program for providing a communication interface mechanism to said first computer program whereby said first computer program may request data records pertaining to one or more selected subjects for which said second computer program generates data records without said first computer program knowing that said second computer program generates data records on said subject or where said second computer program is, said subject-based addressing means for establishing communications with said second computer program in the form of a subscription request whereby said second computer program automatically sends all data records pertaining to said subject or subjects to said first computer program.

13. The apparatus of claim 12 wherein said subject-based addressing means includes service discipline means for establishing said communication with said second computer program using the appropriate communication protocol used by said second computer program.

14. The apparatus of claim 13 wherein the original subscription request for data records pertaining to a particular subject includes the name of a callback software program, and wherein said service discipline means includes means for sending a subscription request to said second computer program which includes the subject or subjects of interest and an address to which an acknowledgment message by said second computer program is to be sent if data records on said subject or subjects can be supplied and a second address to which the data records pertaining the subject or subjects are to be sent, said service discipline means including means for passing said data records received from said second computer program to said callback software program.

15. An apparatus for decoupling a first software application from the need to know the address, service name, or prococol of a service software application with which data is to be exchanged, comprising:

directory-services means for electronically storing data mapping particular subjects to the addresses of services which supply data regarding particular subjects and to the name of an associated service discipline for each said service which defines a communication protocol for exchanging data with said service;

one or more service discipline means for establishing subscription communication links with the associated

services by which said service sends only data regarding a particular subject to said associated service discipline means, and for passing data regarding said subject received from said service to said first software application;
subject mapper means coupled to said first software application and to said directory-services means for receiving a subscription request from said first software application requesting data regarding a particular subject and for electronically searching said directory-services means to find the address of a service running on a server computer which supplies data regarding said subject and the name of said associated service discipline which defines how data exchanges with said service are to be carried out and for passing the subject data in said subscription request to the service discipline means identified by access to said service directory means and causing said service discipline means to establish a said subscription communication link with the associated service.

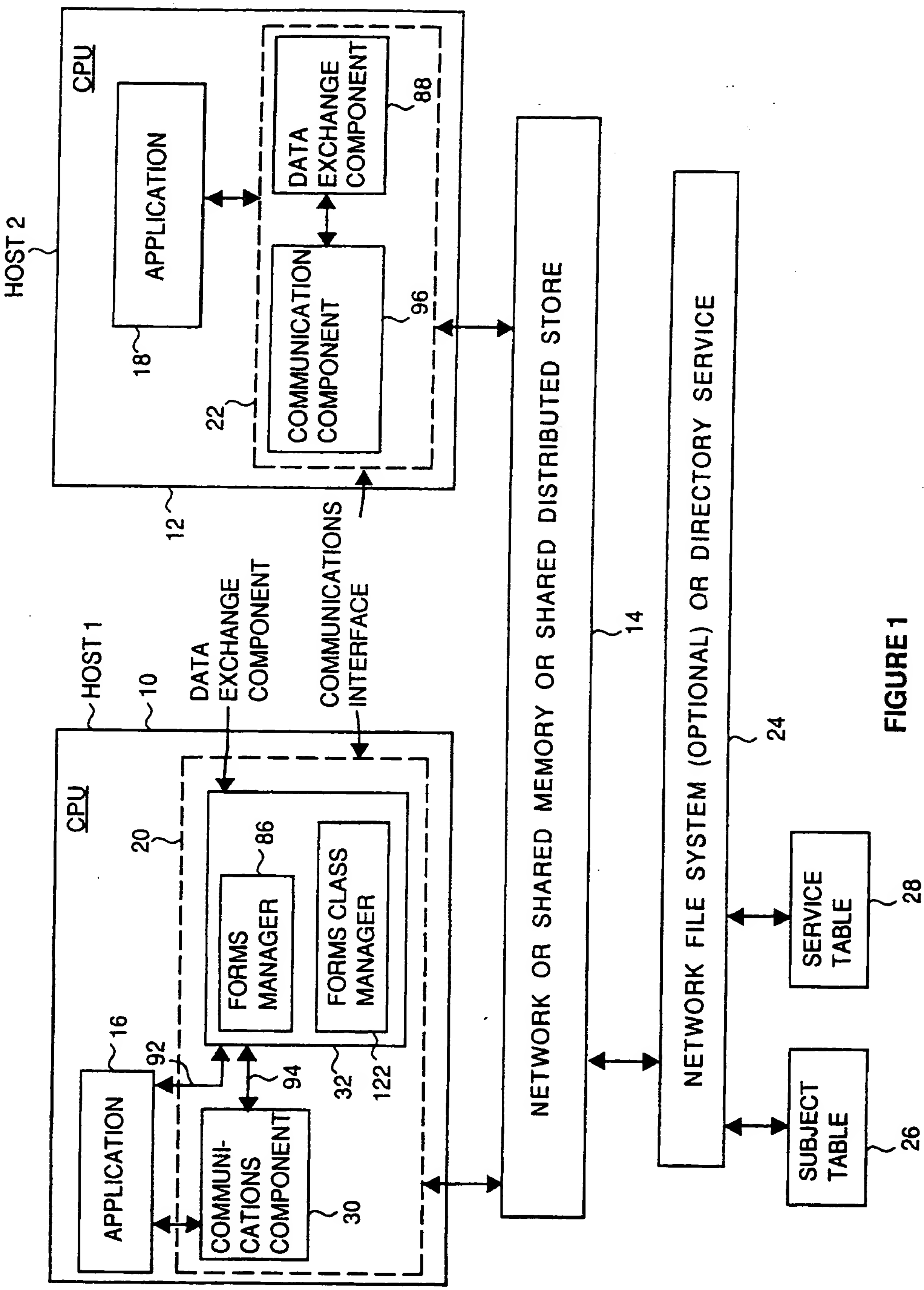

HOST 1
10
CPU
20
APPLICATION
16
92
COMMUNI-
CATIONS
COMPONENT
30
94
FORMS
MANAGER
86
FORMS CLASS
MANAGER
32
122
DATA
EXCHANGE
COMPONENT
COMMUNICATIONS
INTERFACE
HOST 2
12
CPU
APPLICATION
18
22
COMMUNICATION
COMPONENT
96
DATA
EXCHANGE
COMPONENT
88
NETWORK OR SHARED MEMORY OR SHARED DISTRIBUTED STORE
14
NETWORK FILE SYSTEM (OPTIONAL) OR DIRECTORY SERVICE
24
SUBJECT
TABLE
26
SERVICE
TABLE
28

FIGURE 1

EXAMPLE FORM CLASS DEFINITIONS

PLAYER _ NAME: CLASS 1000
RATING: FLOATING _ POINT CLASS II
AGE: INTEGER CLASS 12
LAST _ NAME: STRING _ 20 _ ASCII CLASS 10
FIRST_ NAME: STRING _ 20 _ ASCII CLASS 10

**FIGURE 2**

PLAYER _ ADDRESS: CLASS 1001
STREET: STRING _ 20 _ ASCII CLASS 10
CITY: STRING _ 20 _ ASCII CLASS 10
STATE: STRING _ 20 _ ASCII CLASS 10

**FIGURE 3**

TOURNAMENT _ ENTRY: CLASS 1002
TOURNAMENT _ NAME: STRING _ 20 _ ASCII CLASS 10
PLAYER: PLAYER _ NAME CLASS 1000
ADDRESS: PLAYER _ ADDRESS CLASS 1001

**FIGURE 4**

STRING _ 20 _ ASCII: CLASS 10
STRING _ 20 ASCII
INTEGER: CLASS 12
INTEGER _ 3
FLOATING - POINT : CLASS 11
FLOATING _ POINT _ 1/1

**FIGURE 5**

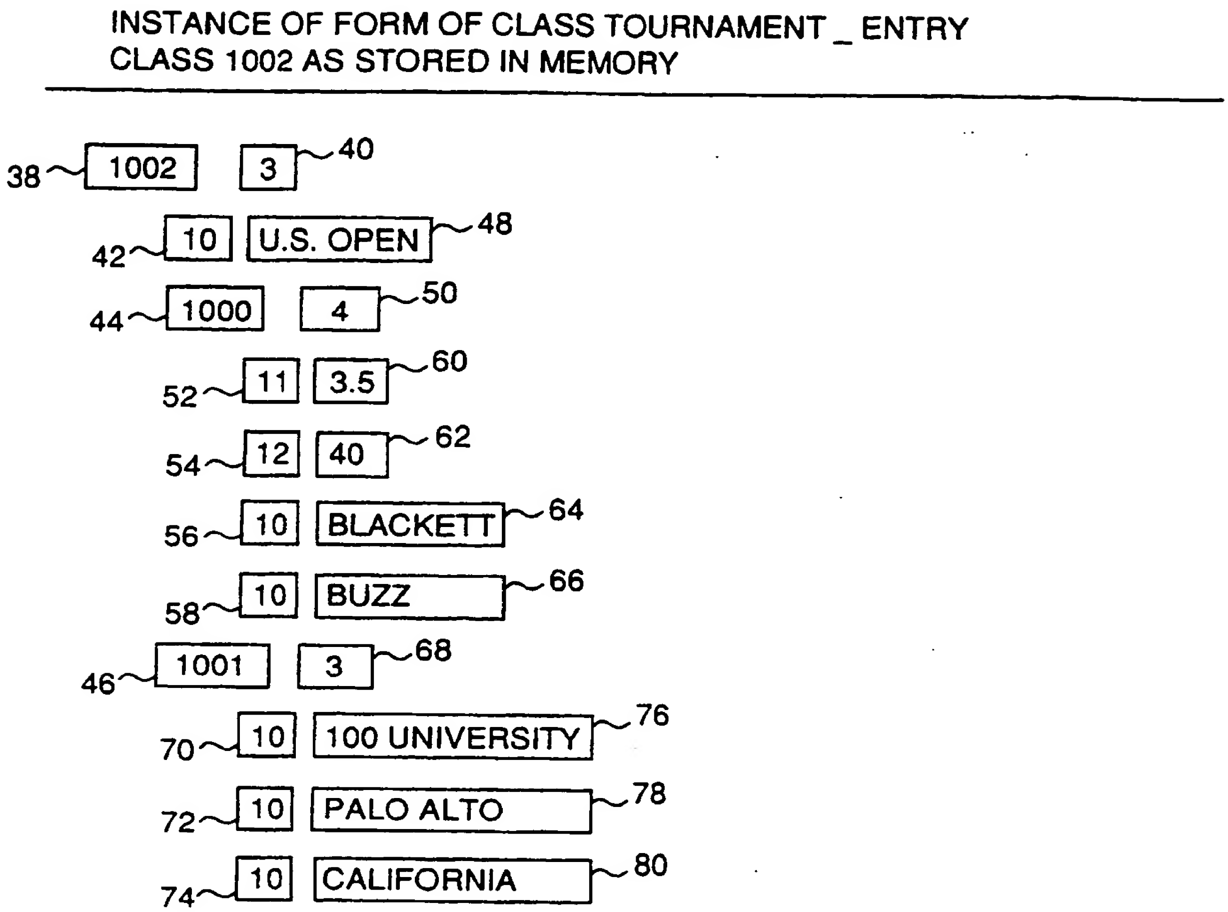



FIGURE 6

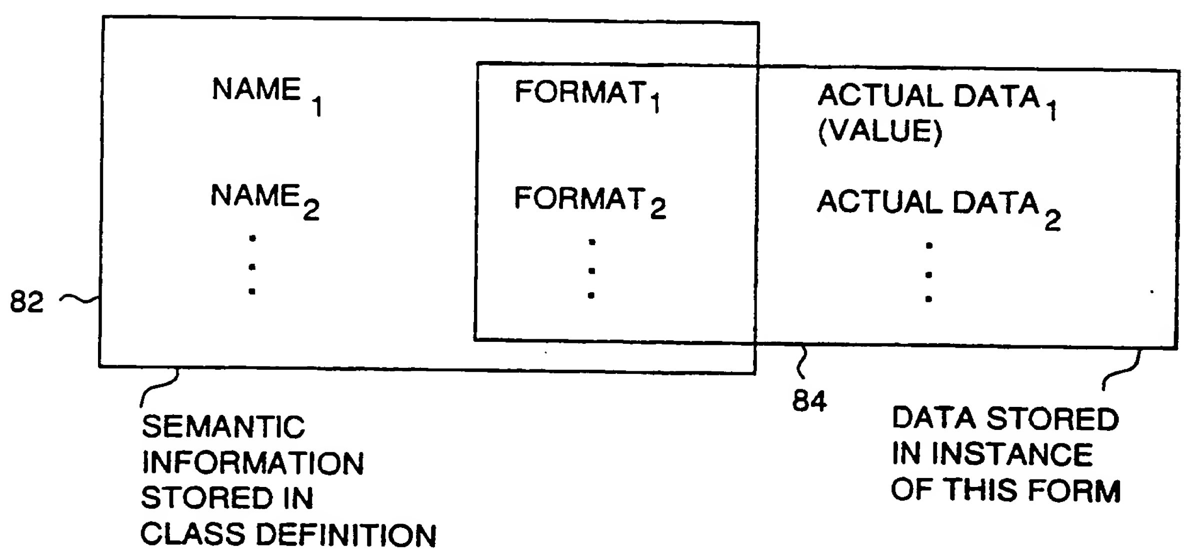
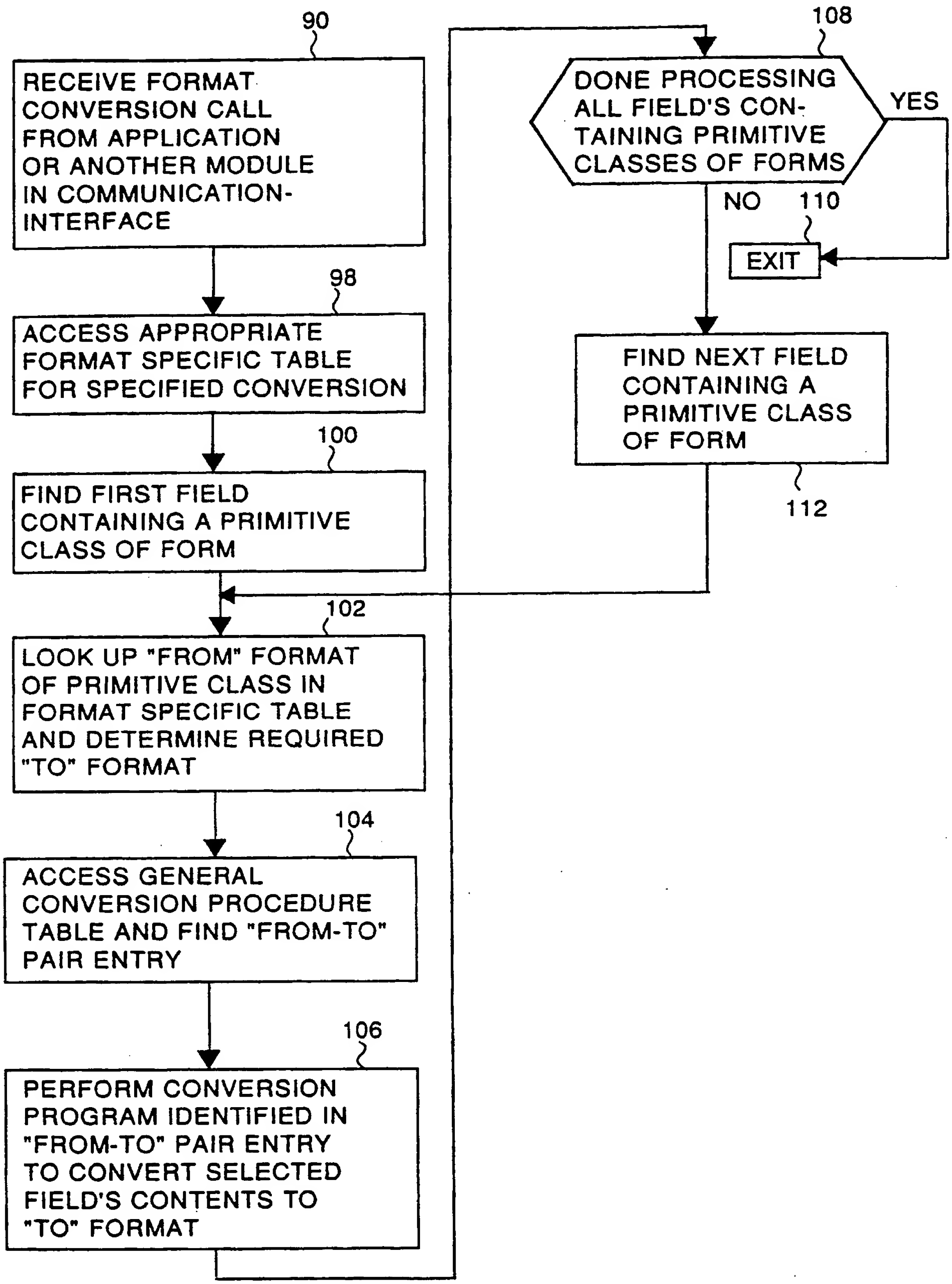



FIGURE 7




FORMAT OPERATION
**FIGURE 8**

DEC TO ETHERNET™

| FROM | TO |
|---|---|
| 11 | 15 |
| 12 | 22 |
| 10 | 25 |
| . . . | |

FIGURE 9

ETHERNET™ TO IBM

| FROM | TO |
|---|---|
| 15 | 31 |
| 22 | 33 |
| 25 | 42 |
| . . . | . . . |

FIGURE 10

GENERAL CONVERSION PRODECURES TABLE

| FROM | TO | CONVERSION PROGRAM |
|---|---|---|
| 11 | 15 | FLOAT I _ ETHER |
| 12 | 22 | INTEGER I _ ETHER |
| 10 | 25 | ASCII _ ETHER |
| 15 | 31 | ETHER _ FLOAT 2 |
| 33 | 22 | ETHER _ INTEGER |
| 42 | 25 | ETHER _ EBCDIC |
| . . . | . . . | . . . |

FIGURE 11

SEMANTIC-DEPENDENT PROCESSING

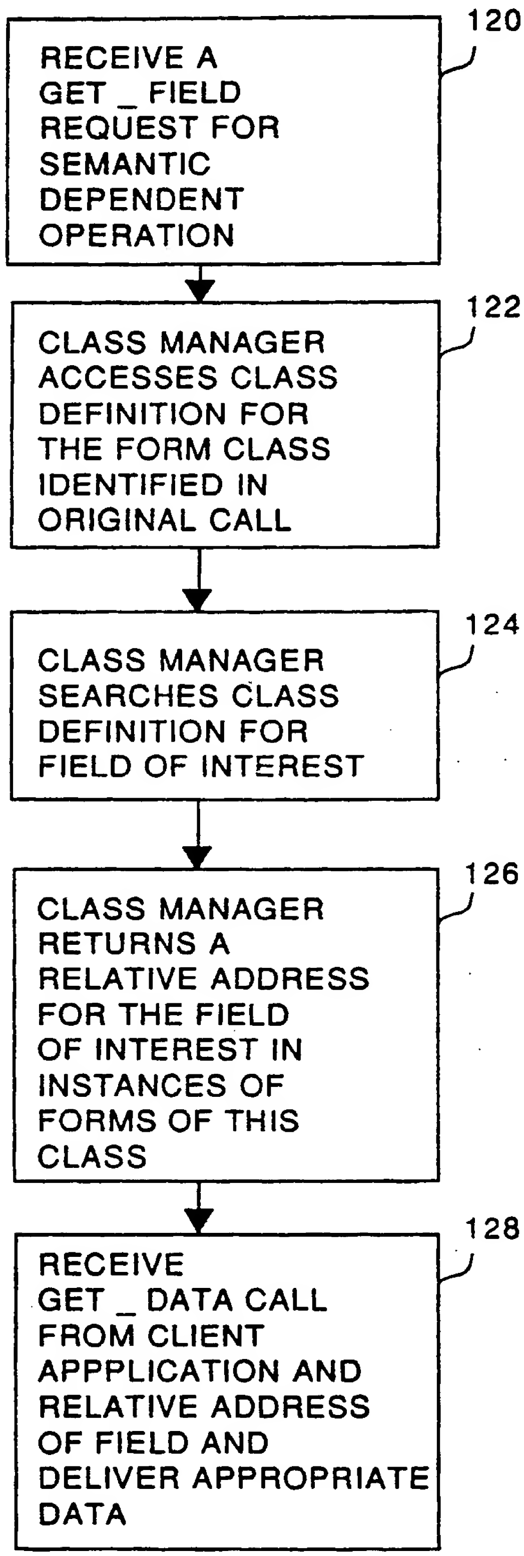



**FIGURE 12**

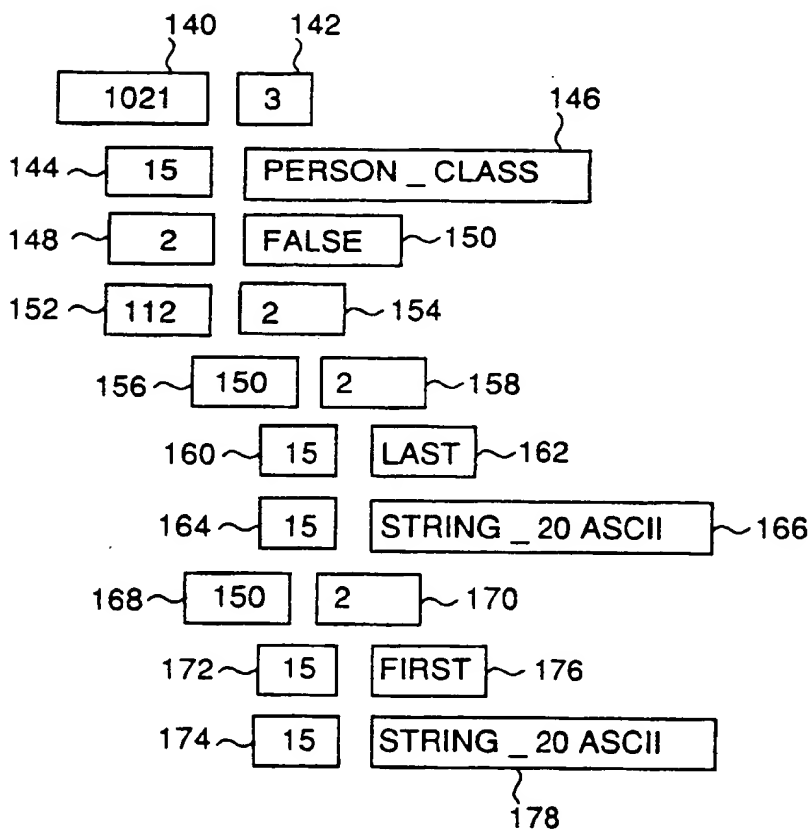
PERSON _ CLASS: CLASS 1021

LAST: STRING _ 20 ASCII

FIRST: STRING _ 20 ASCII

CLASS DEFINITION

**FIGURE 13A**




CLASS DESCRIPTOR STORED
IN RAM AS A FORM

**FIGURE 13B**

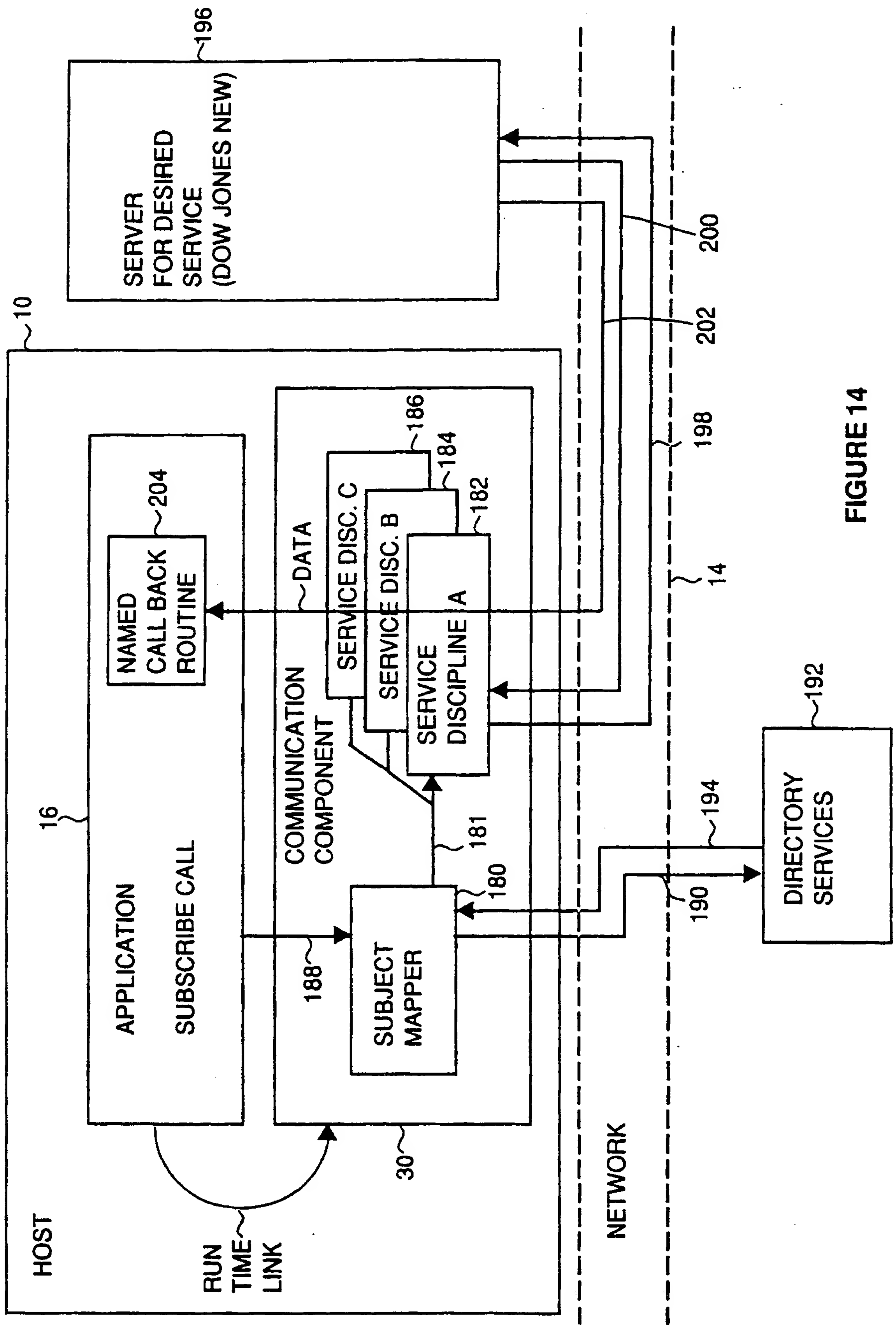

SERVER
FOR DESIRED
SERVICE
(DOW JONES NEW)
196
10
200
202
198
14
HOST
APPLICATION
SUBSCRIBE CALL
16
NAMED
CALL BACK
ROUTINE
204
DATA
COMMUNICATION
COMPONENT
SERVICE DISC. C
186
SERVICE DISC. B
184
SERVICE
DISCIPLINE A
182
181
SUBJECT
MAPPER
180
188
30
RUN
TIME
LINK
NETWORK
DIRECTORY
SERVICES
192
194
190

FIGURE 14

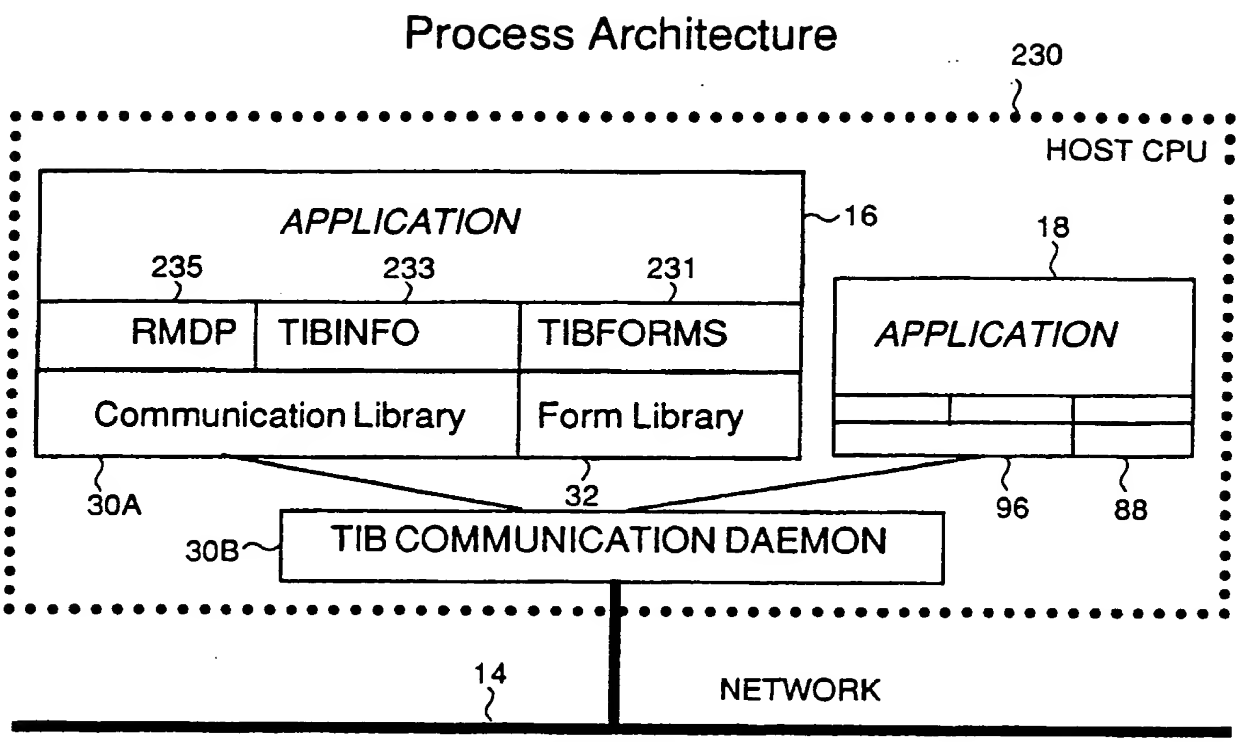



FIGURE 15

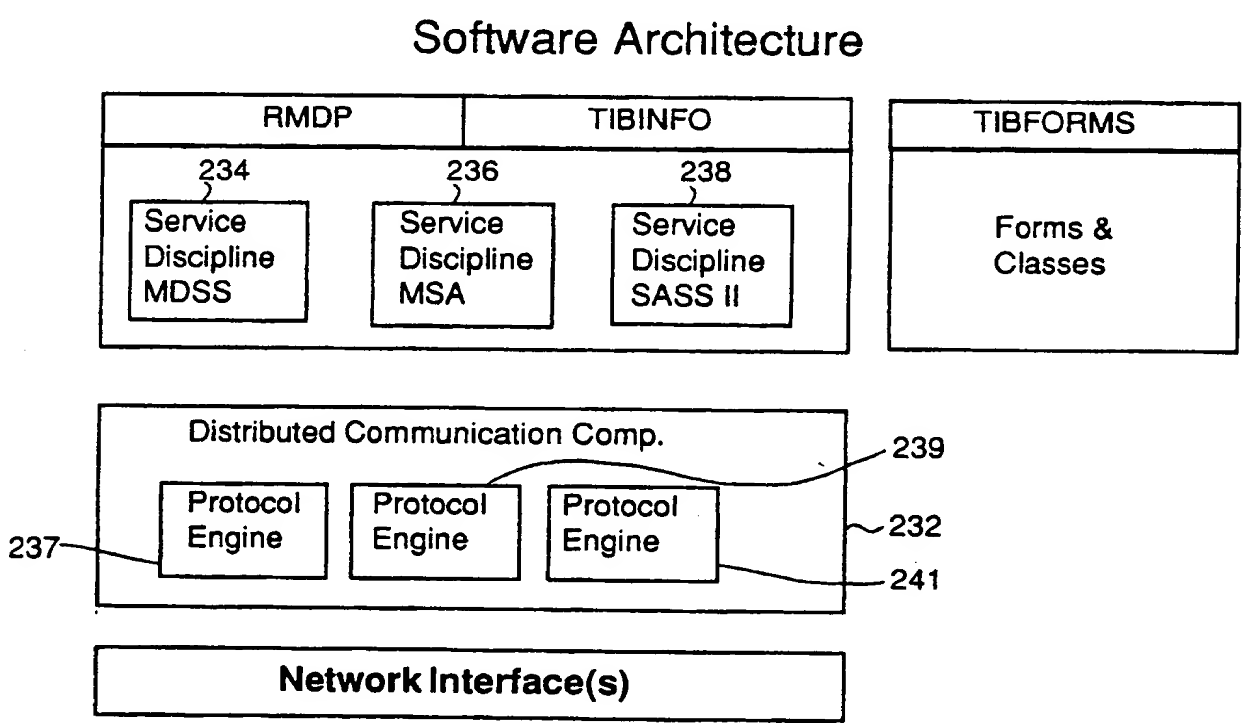



FIGURE 16

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## (54) Apparatus and method for providing high performance communication between software processes.

(57) A communication interface for decoupling one software application from another software application such communications between applications are facilitated and applications may be developed in modularized fashion. The communication interface is comprised of two libraries of programs. One library manages self-describing forms which contain actual data to be exchanged as well as type information regarding data format and class definition that contain semantic information. Another library manages communications and includes a subject mapper to receive subscription requests regarding a particular subject and map them to particular communication disciplines and to particular services supplying this information. A number of communication disciplines also cooperate with the subject mapper or directly with client applications to manage communications with various other applications using the communication protocols used by those other applications.

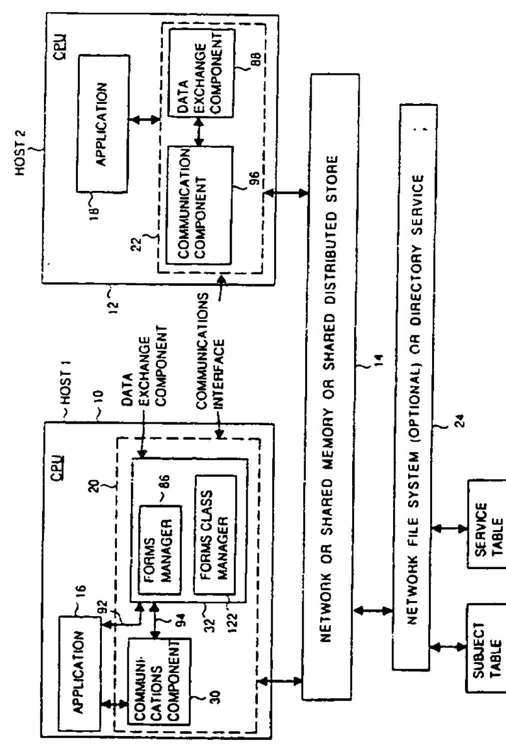

FIGURE 1

EP 0 412 232 A3

European Patent Office

# EUROPEAN SEARCH REPORT

Application Number

EP 90 10 1037

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl.5) |
|---|---|---|---|
| X | IBM JOURNAL OF RESEARCH AND DEVELOPMENT vol. 20, no. 5, September 1976, NEW YORK US pages 483 - 497 V. Y. LUM ET AL 'A general methodology for data conversion and restructuring' * the whole document * | 1 | G 06 F 9/46<br>G 06 F 15/16<br>G 06 F 15/20 |
| A | EP-A-0 216 535 (TRW INC) 1 April 1987 * page 5, line 3 - page 8, line 9; claims 1,2,3 * | 1,2,6, 10 | |
| A | IBM TECHNICAL DISCLOSURE BULLETIN. vol. 28, no. 5, October 1985, NEW YORK US pages 2160 - 2161 'Revisable form document conversion' * the whole document * | 1 | |
| A<br>A | EP-A-0 167 725 (HITACHI LTD) 15 January 1986 * claims 1,3 * | 1 | |
| A | EP-A-0 130 375 (IBM CORP) 9 January 1985 * page 2, line 8 - page 2, line 34 * | 1 | TECHNICAL FIELDS SEARCHED (Int. Cl.5)<br>G 06 F |

~~The present search report has been drawn up for all claims~~

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 11-01-1993 | MICHEL T G |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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P : intermediate document

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L : document cited for other reasons

& : member of the same patent family, corresponding document

European Patent Office

## CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

☐ All claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for all claims.

☐ Only part of the claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid,

namely claims:

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

## LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirement of unity of invention and relates to several inventions or groups of inventions,

namely:

See Sheet B.

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid,

namely claims:

☒ None of the further search fees has been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims,

namely claims: 1-14

European Patent Office

EP 90101037 -B-

## LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirement of unity of invention and relates to several inventions or groups of inventions, namely:

1. Claims: 1-14 : Interface for proceeding a format conversion during the exchange of data between two applications.

2. Claims: 15 : Interface for requesting data on a subject and mapping the request to the service supplying the information.